JOURNAL

of the

AMERICAN CONCRETE INSTITUTE

Published monthly except July and August by the
American Concrete Institute under the authority of the Board of Direction

EDITED BY THE SECRETARY

with the direction of the PUBLICATIONS COMMITTEE: W. A. SLATER, chairman; P. H. BATES, ARTHUR R. LORD, J. C. PEARSON, A. N. TALBOT, BENJAMIN WILK, HARVEY WHIPPLE, Secretary.

Papers: Original papers, furthering the objects of the society, are invited. They should be addressed to the Secretary, and their consideration by the Publications Committee will be facilitated if: (1) a brief but comprehensive outline or summary precedes or at least accompanies the completed paper; (2) manuscript and photographs are available in duplicate or triplicate; (3) original tracings or other drawings, from which copies are readily made, are available.

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Subscription price $12.50 per year payable in advance. To members, $10.00 per year, included in the annual dues.

Bound volumes 1 to 22 of *Proceedings of the American Concrete Institute* (1905 to 1926)—$8.00 each so far as available; Volumes 23, 24, 25 (1927-1929) $10.00 each. To members $5.00 each. Volume 26 (1930) consisting of JOURNAL issues 1-8, November 1929-June 1930, bound without *News Letter* pages to non-members and non-subscribers, $12.50. Subscribers and members may obtain the volume (in addition to their monthly issues) at the end of the volume year at $6.00, so long as a limited supply of over-copies permits. Members may insure availability of not more than two copies of each volume at a special price when they place their orders in advance of the first JOURNAL issue of each volume.

Publication address: 2970 West Grand Boulevard, Detroit, Michigan. Entered at the Post Office at Detroit, Michigan, as mail of the second class under the provisions of the Act of March 3, 1879.

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Founded 1905; incorporated 1906 (National Association of Cement Users); charter amended 1913. (American Concrete Institute.)

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VOL. 2—NO. 1 SEPTEMBER 1930 (*Proceedings Vol. 27*)

JOURNAL
of the
AMERICAN CONCRETE INSTITUTE

News AMERICAN CONCRETE INSTITUTE Letter

BOUND VOLUMES

THOSE of you who have ordered extra bound copies of *Proceedings*, Vol. 26, with the *Abstracts* (which are gathered in the back of the book) should receive them about the time this JOURNAL reaches you—if printer and binder predictions are made good.

Those members of the Institute who want Vol. 27 next summer, (in addition to the monthly JOURNALS) containing *Proceedings* and *Abstracts*, Sept. 1930 to June 1931 inclusive and minus *News Letter* pages, can have the necessary extra pages printed, stored and bound for them, uniform with previous volumes, at a special member price of $3.00. This price is good only until October 1. The $3.00 price is to those only who order *now* so that the extra pages can be printed as each JOURNAL goes to the press.

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If your JOURNALS are not available for handling in this general lot on November 1, the price will be $2.10.

In either instance *notify* this office that your JOURNALS are being sent to the Michigan Book Binding Co. and send your remittance to the American

Concrete Institute *with* your notice of shipment.

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If you don't want to depend upon the uncertainty of saving your JOURNALS from now until next June for Vol. 27, you may for $3.00, paid in advance to the Institute, secure a complete bound volume postpaid at the end of the volume year in addition to your monthly JOURNALS. Such an order must be from a member of the Institute and must be received by October 1, 1930. After October 1, the member price jumps to $6.00.

The reason is this: By having your order in advance we can at small additional cost per month provide extra forms of *Proceedings* and *Abstracts* pages which are stored until the volume is complete. If you order later you draw upon a limited supply of over copies provided to meet orders from non-members at $12.50 each.

Order at once $3.00. Order later the price is double. Order as a non-member the price is $12.50, because the non-member should thus share with the member the cost of the years's work which the member pays for with his dues.

THE 1931 CONVENTION, MILWAUKEE, FEBRUARY 24-26

IF THE alacrity of a local committee in taking hold of its job is at all significant, those who go to Milwaukee for the 27th annual convention at the Schroeder Hotel, February 24-26 next will find it worth while in all those many conditions surrounding conventions which make them memorable.

The Milwaukee group is rather proud of the relationship it bears to the field of concrete. It makes a great deal of equipment that figures strongly in the primary stages of concrete; that is, in making the cement; and it supplements cement mill equipment with contractor's job equipment of wide use and fame.

K. H. Talbot of the National Equipment Corporation, is General Chairman of the Milwaukee Convention Committee.

D. R. Collins—familiarly, in fact, generally known as "Spec," for a long time potent inspirer of better things in the concrete products industry, and now president of the Concrete Masonry Association (successor to National Concrete Products Association), is the enthusiastic and ingenious Secretary of the Committee.

Talbot and Collins have enlisted the support of the following members of the Milwaukee Convention Committee:

B. E. Brevik—Portland Cement Association

H. S. Greene—Chain Belt Co., 736 Park St.

E. R. Ferguson—Milwaukee Ass'n of Commerce

R. C. Newhouse—Allis-Chalmers Co., West Allis, Wis.

W. P. Hirschberg—Consulting Engineer, 440 Milwaukee St.

T. J. Baker—Coddington Engineering Corp., 290 3rd St.

A. W. Devos—Wm. H. Devos Co., 3115 Auer Ave.
H. L. Foster—Foster Engineering Co.
C. A. Wiepking, City Testing Engineer, Milwaukee
Jack Franklin—Franklin Equipment Co., 123 Wisconsin Ave.
L. S. Brodd, Portland Cement Ass'n, 425 East Water St.
Jerry Donohue—Chairman. Wisconsin Highway Commission, Madison
R. C. Johnson—Immel Constr. Co. Fond du Lac.
William F. Tubesing—Wm. Tubesing Co., Inc., 708 Oakland Ave.
F. W. Ullius—Milwaukee City Engineers Office
E. G. Lichtenberg—Koehring Co., 31st and Concordia Ave.
Henry C. Hengels—American Institute of Architects.
C. U. Smith—Harbor Board
Robert Cramer—Milwaukee Sewerage Commission
Leon M. Gurda—Milwaukee Building Department
M. S. Hunter—Hunter Machinery Co., 16th and Viaduct
William F. Cavanaugh—Milwaukee County Highway Commission

The fact that Wisconsin has for several years had a concrete products group unusually active and progressive and a state association whose annual convention has attracted concrete building unit manufacturers in large numbers from other states, is being given full consideration by the Institute's Program Committee—P. H. Bates, Chairman. Mr. Collins has pledged to the success of Institute convention week the full cooperation of the products groups. The Wisconsin group will undoubtedly merge its annual meeting with the Concrete Masonry Association (National) and it in turn give first thought to that part of the Institute's program which will be devoted to the concrete masonry field. The Masonry association's own meeting will be devoted very largely to selling and the numerous purely commercial problems of the field.

The Program Committee has under development a session devoted entirely to light weight concrete—approaching the subject from two angles: first a detailed consideration of the characteristics of two of the most used aggregates of light weight—cinders and burned clay and second from the design angle in an analysis of what reduced weight means in construction economy.

It is probable that another full session will be given to papers and reports bearing on the now all-important theme: The durability of concrete.

Several papers of outstanding importance on research, design and construction subjects are in the making. More detailed announcements will be made next month.

WASHINGTON, 1932

AND WHILE the Milwaukee Convention Committee is getting enthusiastically under way to make the 27th annual meeting next February a notable one in all its local arrangements, it is not too soon to announce that the 28th annual convention will be in Washington, D. C.—the week of February 22, 1932.

It will be the second Institute convention in Milwaukee (National Association of Cement Users, 1906) but the first meeting in the nation's capital.

The preliminary arrangements have been made in carrying out the new policy of the Board to plan meetings farther in the future, and with some

thought of alternate accommodation of membership east and west. The headquarters will be at the Wardman Park Hotel.

THE INDEX AND INDEXING

TITLE, Contents and Index pages—to the total number of XL—published as a supplement to the first completed volume of the JOURNAL—November 1929-June 1930—are printed and should reach most members of the Institute before you can read these lines.

They are for your convenience in referring to the *Proceedings* pages, 1-945 of Vol. 26, and to the *Abstracts*, pages 1-129 published in the JOURNAL, January to June.

A satisfactory index is a silent guide that leads you by the shortest route to the subject which interests you—*no matter what term you use to designate that subject or by which of many mental routes you approach it.*

Therein is the key to the difficulty of a satisfactory index. The Publications Committee does not give the index unanimous and hearty approval; the Editor is not wholly pleased with the result and least satisfied of all is the man who did the job—Dwight F. Jennings. Yet, what is most significant, the individuals who comprise this critical group are far from agreement in their criticism.

The nomenclature, the idea classification, of the field of concrete is far from static. That fact springs from another, that much of what we call knowledge of concrete is in a state of flux. We are revising that knowledge from day to day; call things by a variety of names and classify them with greatest diversity. All of which gives point to the Institute's whole task.

Before the job was started—before the June JOURNAL had, as the printers say, been put to bed—Mr. Jennings sought astute advisors to establish an outline by which the diverse literature of cement and concrete might be arranged in some orderly fashion. He immediately found great difference of opinion as to a series of word "handles" by which to get hold of the various departments of knowledge.

To any one man, conversant with concrete literature for some time, a consistent and regular contributor to that literature, accustomed to the nice distinctions of classification, indexing is all fairly simple. It becomes complicated only when two or more such competent persons are brought together. Agreement in fashioning an outline is very rare.

Cross-indexing has been generously done but for all the length to which it runs, is probably not generous enough. The indexer, as is the invariable habit of indexers, has probably failed to recognize a subject by the term you will at once apply.

There will be other indices in the years to come and thoughtful suggestions at once to simplify and to amplify will always be welcome. It will be well to bear in mind that an index to any one volume does not stand alone and independent. Eventually it becomes a part of a cumulative index. The index which points to the subject matter in Volume 27, *next* summer, should be as it was sought to make the index to Volume 26, a framework so broadly articulated that a ten year program can be shaped to its outline.

See announcement about Bound Volumes, page 1.

TECHNICAL COMMITTEES

AT ITS meeting May 10 the Board of Direction authorized a number of new Committees and Committee Chairmen. Since then further committee undertakings have been approved by the Board's Executive Committee.

For the technical committee list as of March 1, 1930, see 1930 A. C. I. Directory, p. 10. Announcements of some new committees and committee changes were made in the JOURNAL, *News Letter*, page 3, May, 1930. There follow references to additional new committees (designated "new committee") so far as organization is partially effected, and other committee appointments and changes, together with repetition of reference to those new committees first announced in May (designated "1930 committee"). Thus the present list completely supplements the 1930 Directory list:

DEPARTMENT 100, RESEARCH

102—Volume Changes in Concrete

G. E. Troxell succeeds R. E. Davis as author chairman, Professor Davis remaining a member. Will take up committee's report of Feb. 1930, summarizing results of numerous investigations of volume changes due to causes other than stress, and using the reported data, prepare a digest, setting forth the indicated significance of the summarized data in applications of concrete, as a basis of design and construction practice.

105—Reinforced Concrete Column Investigation

P. H. Bates, Bureau of Standards, becomes an additional member.

106—(1930 Committee) Effect of Vibration on Properties of Concrete

Author-Chairman—W. A. Slater. To present a summary of available information—methods of vibrating; initial and final consistency; proper w/c ratios; use on massive structures, buildings, for high strength columns in concrete products plants; machines and labor, effect on properties of concrete.

107—(New Committee) Properties of Job Cured Concrete at Early Ages

Author-Chairman—Harlan H. Edwards; critic members to be appointed. To report on the basis for safe formwork removal, road opening, products handling, etc., discussing effect of curing conditions (temperatures and moisture); effect of cements; effect of w/c ratio; effect of aggregates; discussing design of roads, buildings, products to permit of use at earliest ages, and with lesser strengths.

108—(New Committee) Heat Developed in Concrete

Chairman, Raymond E. Davis; P. H. Bates, L. C. Hill, F. R. McMillan D. C. Henny. (additional members to be added). To discuss effect of w/c ratios; rate of generation and dissipation; effect of mass of concrete; effect of pressure above—variation in depth to point considered: effect of formwork-insulation; is it safe to keep all chemical heat in by insulation?; methods of insulating; relation of shrinkage to internal temperatures—also rate of shrinkage.

109—(New Committee) Summary of Plastic Flow

Author - Chairman — Raymond E. Davis; (critic members to be announced

later). In the work of Committee 102 on Volume Changes, Professor Davis excluded volume changes due to stress, making this subject and its effect in redistributing moments, the basis of a separate report.

110—(New Committee) Use of Admixtures in Concrete

Author - Chairman — Ben Moreell; (the members of the committee to be named). To report a summary of available information, defining admixture as anything added to concrete beyond the essential cement, water, fine and coarse aggregate and answering as far as possible, all questions contained in "Questionnaire for Admixture Salesmen," in first article "In Constant Repair" by Arthur R. Lord in January 1930 JOURNAL, *News Letter*, p. 11.

DEPARTMENT 200—MATERIALS

203—(1930 Committee) Cinders as an Aggregate for Concrete

Author-Chairman—Einar Christensen. To present summary—proper sources of supply; proper treatment; tests for suitability for use for various purposes, including products and monolithic concrete; proper storage and handling; effect on properties of concrete (as compared with ordinary aggregate) such as weight, strength, E_c; permeability, permanence, etc.; effect on reinforcement—in presence of water leaks and in dry locations. See also November 1929 JOURNAL, *News Letter*, p. 9.

204—(New Committee) Burned Clay or Shale Aggregates

Author-Chairman—George E. McIntyre; committee members to be named. To discuss: Methods of manufacture in various plants; materials used; variation in properties, such as weight, voids, pores, absorption, etc., variation in properties of concrete, such as weight, strength, permeability, permanence, resistance to freezing and thawing, absorption, sound transmission, heat transmission, etc. Discuss: considerations arising on job in handling this material, on account of its weight, absorption, harshness, etc.

205—(New Committee) Grading of Aggregates for Handling on Job

Author - Chairman — I. E. Burks; members to be announced. To discuss: effectiveness of gap in grading to prevent "unravelling" in stock piles; how wide a gap is necessary; where in range of sizes is gap most desirable; is effect the same as to separation (unravelling) of concrete itself; effect of gap on properties of concrete; effect on amount of mortar required in concrete; effect on workability and placing —with dry vibrated mix and with plastic mix.

DEPARTMENT 300, ENGINEERING DESIGN

302—Design of Two-Way Slabs on Beams

Chairman, E. H. Uhler; members, F. E. Brown, S. G. Cutler, A. E. Lindau, A. R. Lord, W. A. Slater, W. F. Zabriskie. Committee authorized 1929 now fully organized.

304—Fire Resistance Standards in Design

Author-Chairman—N. D. Mitchell; critic members, R. L. Bertin, T. D. Mylrea, R. R. Zipprodt, F. R. McMillan, R. W. Johnson. A 1929 committee reorganized.

307—Deflections of Reinforced Concrete Members

Author-Chairman—T. D. Mylrea; critic members, P. J. Freeman, Fred Kubitz, A. H. Saurbrey. Professor Mylrea, appointed 1929, prepared a

partial report, since referred to critic members.

308—(1930 Committee) Basis of Design for Hurricane Exposures

Author - Chairman — Albert Smith. Discuss: Probable wind velocity and pressures on various types, shapes and sizes of structures; vertical variation in intensity of pressure; suction; sway and gusts of wind; foundation anchorage; stability; method of design, as by lowering stresses or by increasing and properly evaluating loads; effect of neighboring structures; release of pressure by failure of windows, etc., roof signs, etc.

309—(New Committee) Minimum Permissible Thickness of Slabs and Walls

Author-Chairman—D. E. Parsons; critic members to be announced. To discuss: considerations of strength, such as heights of wall, length of wall, size of span, backling, etc., considerations of rigidity such as initial deflection added deflection due to plastic flow, etc.; and considerations of fire safety, such as indicated by burn-out tests, experience in actual fires, etc. Compare requirements for various members such as floors, walls, partitions, and for various materials permitted, such as concrete, brick, tile, gypsum, etc.

310—(New Committee) Effect of Settlement of Foundation in Reinforced Concrete Structures

Chairman, Hardy Cross; members to be announced. To discuss: effect of soil conditions; actual observed settlements on spread footings on piles of various kinds and on belled-out cylindrical piers; effect on various common systems of floor framing, such as slab on girders, etc.; effect of concrete quality; effect of plastic flow in the concrete; means of taking up settlement, such as built-in jacks, etc.; effect of rate of settlement.

311—(New Committee) Moment of Inertia of Reinforced Concrete Members

Author-Chairman, F. E. Richart; critic members to be announced. To discuss: general degree of importance of this item in design; effect of quality of concrete; effect of amount (ratio), and distribution of reinforcement; suitable formulas for various types of members, such as tied, columns, spiral columns, usual systems of slab, beams and girder (each direction), joists and girder (each direction), two-way slab on girders, flat slab, etc., effect of concrete in tension; effect of brackets, etc.

DEPARTMENT 400, ARCHITECTURAL DESIGN

404—Composite Concrete Structures

Author-Chairman, J. Morrow Oxley; critic members to be announced. Committee reorganized since first announced.

406 — (1930 Committee) Use of Lightweight Concrete in Buildings

Author-Chairman, Frank A. Randall; critic members to be announced. To discuss: Savings in weight by means of various systems of floor framing; available light-weight concrete—Haydite and cinder concrete—and proper application of each; use of light-weight concrete products for walls and partitions; use as a base for stucco; savings in columns and foundations; extra story before changing from spread footings to piles; or from piles to caissons; acoustical and insulating results, etc.

407—(1930 Committee) Painting on Concrete Surfaces

Author-Chairman, Maximilian Toch; critic members to be announced. To discuss: Effect of cement, aggregates, oiling of formwork, curing of concrete; effect of condition of surface, rough or smooth, form works, honey comb, sand streaks, porous or dense, etc., effect of drying out vs. painting on green concrete; suction desirable; alkalies, etc. in concrete that would injure or cover up the paint; proper preparation of surface; proper kinds of paint; proper method of application for each kind; proper treatment after applying for each kind; outdoor and indoor exposures; etc.

408—(New Committee) Recommended Practice for Use of Color in Concrete

Chairman, W. D. M. Allan; members, C. A. Cooke, John G. Ahlers, M. R. Rust, Joseph W. Ayers, John Mott, Edward M. Waldo, Rexford Newcomb. The assignment is implied in the title. The committee will propose a recommended practice for the use of color in concrete.

DEPARTMENT 500, SPECIFICATIONS

501—Standard Building Code

New members added to the committee, Miles N. Clair, S. C. Hollister, R. W. Johnson.

507—(New Committee) Purchase Specifications for Metal Supports for Reinforcement

Author-Chairman, W. E. White; critic members to be named. To propose specifications based on consideration of quality of steel (spring steel?) required for effective support; amount of load to be carried without permanent sag (men carrying runway sections, bars, etc.) chairs for support of steel in top; spacers and chairs for bottom steel; separators for several layers of bars in beams; wall steel supports; form work ties and spreaders; C. R. S. I. standards for number and arrangement; marking for identifications.

508—(New Committee) Concrete Foundations for Steel Buildings

Author-Chairman, J. E. Hough; critic members to be named. To prepare a specification especially for this very common use of concrete—would apply equally to wood buildings or brick and wood buildings. Parallel to proposed specifications 502 and 503 but taking into account problems of foundation water; undersized excavation; caisson water; caisson filling; removing caisson rings and lagging; problems due to shoring and braces; setting very heavy steel in foundation girders.

DEPARTMENT 600, FIELD CONSTRUCTION

602—Design and Operation of Central Mixing Plants

J. E. Burke appointed to membership succeeding Edward Jones, resigned.

605—(New Committee) Settlement of Concrete in Forms

Author-Chairman, James Lindon; critic members to be named. To discuss: Probable amount of settlement; effect of materials, consistency, w/c ratios, method of placing, etc;. effect of amount and nature of vibration; does rising water (water gain) cause segregation of other materials?; effect of reinforcement—water gathers at under surface—effect on bond, etc.; effect of rate of concrete placing; effect of mass; effect of weather conditions; relation of shrinkage; when does *settlement* end and shrinkage begin?

606—(New Committee) Design of Concrete Mixtures on the Job

Author-Chairman, F. R. McMillan; critic members to be named. This assignment is conceived as a development of the Institute's "Concrete Primer" written by Mr. McMillan. The Primer sets up the fundamental information about concrete; its sequel would take that knowledge onto the job and tell *how* to apply it.

607—(New Committee) Use of Bulk Cement

Author-Chairman, Herbert Coffman; critic members to be named. To discuss: Type of job for which bulk cement is desirable; how large a plant?; products plant and bulk cement; equipment used; peculiar dangers to be safeguarded; weighing devices and plant arrangement.

DEPARTMENT 700, SHOP MANUFACTURE

701—Standards for Concrete Masonry Units

Chairman, Benjamin Wilk; reorganized membership: R. E. Copeland, Secretary; Nolan Browne, Einar Christensen, E. W. Dienhart, C. J. Herzog, D. E. Parsons, G. O. Payne, A. G. Swanson.

704—Cast Stone Standards

Committee reorganized: Chairman, Fred Weigel; Secretary, C. G. Walker; P. H. Bates, Herman Frauensfelder, J. W. Lowell, Ernest Rackle, C. Van de Bogart.

706—Concrete Pipe

Author-Chairman, W. J. Schlick. To present a report summarizing information on problems of the structural design of concrete pipe lines in ditches, with discussion of the loads upon pipe due to fill and super-loads. and the strengths developed in the ditch with different earth and concrete-cradle, pipe-laying methods, showing the necessity for specifying and securing the width of ditch and the method of pipe laying when the pipe to be used are specified in terms of test strength and when the manufacturer is requested to bid on pipe that will be satisfactory in the completed time. The report will provide also the basis for choosing the most economical, safe construction.

DEPARTMENT 900, JOINT EFFORTS

902—Concrete Pavement Standards

Chairman, F. C. Lang; members to be appointed. This reorganized committee has two assignments: The preparation of new specifications for city concrete pavements, a field offering possibilities for service, as, in general, city pavements of concrete are far behind the standard of rural highways and, (the second assignment contingent) cooperation with other standards-making-agencies of the roads field in bringing to light through the Institute, fundamental data in relation to concrete needed in such standardizing efforts.

903—Joint Committee on Specifications for Concrete and Reinforced Concrete (Institute Representation)

Chairman, S. C. Hollister; members, John G. Ahlers, F. H. Jackson, Ben Moreell, N. M. Stineman. Its assignment: participation in the work of the reorganized "Joint Committee." See elsewhere these pages.

904—Sectional Committee on Plastering (Institute Representation)

J. C. Pearson. Committee sponsored by A. S. T. M., under American Standards Association procedure.

905—Sectional Committee on Specifications for Portland Cement (Institute Representation)

A. C. I. Representatives, functioning under American Standards Association procedure, sponsorship of American Society for Testing Materials, are soon to be named, the sectional committee again becoming active in view of new cement specifications of the A. S. T. M.

906 — Sectional Committee on Methods of Tests of Road Materials (Institute Representation)

Under procedure American Standards Association. J. H. Bateman, R. W. Crum.

907—Highway Research Board (Institute Representation)

Duff A. Abrams, representing A. C. I.

908—Masonry and Reinforced Concrete (Institute Representation)

A committee of the Structural Division, American Society of Civil Engineers; A. E. Lindau, representing A. C. I.

909—New York Building Code Revision (Institute Representation)

An advisory committee for New York Building Code Revision, sponsored by The Merchants Association of New York. John G. Ahlers, representing A. C. I.

A New Joint Committee

THE JOINT COMMITTEE on Specifications for Concrete and Reinforced Concrete was reorganized at a meeting of the representatives of the five parent societies at Atlantic City, N. J., June 27.

W. A. Slater was elected chairman; S. C. Hollister, Vice Chairman; F. R. McMillan, Secretary.

The membership of the committee is as follows:

AMERICAN CONCRETE INSTITUTE

S. C. Hollister, Chairman; Professor of Structural Engineering, Purdue University, Lafayette, Ind.

J. G. Ahlers, President, Barney-Ahlers Construction Co., 110 W. 40th St., New York

F. H. Jackson, Bureau of Public Roads, Washington, D. C.

B. Moreell, Lieut. Commander, Bureau of Yards and Docks, Puget Sound Navy Yard, Bremerton, Wash.

N. M. Stineman, Editor, *Concrete*, Chicago, Ill.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

C. P. Richardson, Chairman; Engineer, Track Elevation, C. R. & I. P. Ry., 431 S. Dearborn St., Chicago

Meyer Hirschthal, Concrete Engineer, D. L. & W. R. R., Hoboken, N. J.

J. B. Hunley, Engineer, Bridges and Structures, C. C. C. & St. L. Ry., Cincinnati, Ohio

J. F. Leonard, Engineer, Bridges and Buildings, Pennsylvania Railroad, 729 Pennsylvania Station, Pittsburgh

A. R. Ketterson, Asst. Engineer of Bridges, Canadian Pacific Ry., Montreal, Que., Canada.

AMERICAN SOCIETY FOR TESTING MATERIALS

C. M. Chapman, Chairman, Consulting Engineer, 105 West 40th St., New York

P. H. Bates, Chief, Clay and Silicate Products Division, Bureau of Standards, Washington, D. C.

A. T. Goldbeck, Director, Bureau of Engineering, National Crushed Stone Association, 1735 14th St., N. W. Washington, D. C.

E. E. Hughes, Vice President, Franklin Steel Works, Franklin, Pa.

L. S. Moisseiff, Consulting Engineer, 68 William St., New York

AMERICAN SOCIETY OF CIVIL ENGINEERS

W. A. Slater, Chairman, Director, Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pa.

M. N. Clair, Vice President, Thompson and Lichtner Co., Inc., Statler Bldg., Boston, Mass.

A. E. Lindau, President, American System of Reinforcing, 7 S. Dearborn St., Chicago

F. E. Richart, Prof., Theoretical and Applied Mechanics, University of Illinois, Urbana

W. S. Thomson, Chief Engineer, Kalman Steel Co., Wrigley Bldg., Chicago

PORTLAND CEMENT ASSOCIATION

F. R. McMillan, Chairman: Director of Research, Portland Cement Association, 33 West Grand Ave., Chicago

D. A. Abrams, Director of Research, International Cement Corp., 342 Madison Ave., New York

Ernest Ashton, Vice President, Lehigh Portland Cement Co., Allentown, Pa.

J. H. Chubb, Manager, Service Department, Pennsylvania-Dixie Cement Corp., 521 Fifth Ave., New York

H. G. Farmer, Manager, Service Bureau, Universal Atlas Cement Co., 208 S. LaSalle St., Chicago

An executive committee was elected which consists of the Chairman and Secretary of the Joint Committee and the chairmen of the three remaining groups.

Committees on Membership and Rules and chairmen of working subcommittees have been appointed as follows:

MEMBERSHIP

L. S. Moisseiff, Chairman

D. A. Abrams J. F. Leonard
F. H. Jackson W. A. Slater

RULES

A. E. Lindau, Chairman

D. A. Abrams C. M. Chapman
S. C. Hollister J. B. Hunley

CHAIRMEN OF WORKING SUBCOMMITTEES

1. Materials Other than Reinforcing—F. H. Jackson
2. Metal Reinforcement—L. S. Moisseiff
3. Proportioning and Mixing—F. E. Richart
4. Forms and Placing—C. P. Richardson
5. Design—S. C. Hollister
6. Details of Construction and Fireproofing—J. F. Leonard
7. Waterproofing and Protective Treatment—P. H. Bates
8. Surface Finish—J. H. Chubb

AGAIN MOLECULAR RATIO

A LETTER FROM E. K. BORCHARD*

THE METHOD of computing molecular ratio described by Mr. Pearson in the May issue of the JOURNAL is sufficiently accurate for all practical purposes, but where absolute accuracy is required should we not follow the method described in the British Standard Specifications for Portland Cement (1925 edition)? In this specification in the test for chemical composition a deduction is required for the amount of lime combining with the sulphuric anhydride present in the cement.

For example, for a cement containing 2% of SO_3, the lime combining with this would be equal to 1.40%, and this would be deducted from the percentage of CaO, in turn lowering the value secured for molecular ratio.

*Technical Service Engineer, Atlas Division, Universal Atlas Cement Company, New York.

IN CONSTANT REPAIR

(A Conversation with Dr. Sam'l Johnson)

Dr. Johnson: A man, Sir, should keep his Friendships in a state of Constant Repair.

The Author: And no less, Sir, his Information.

8. Optional Privileges

BY ARTHUR R. LORD

Members of the American Concrete Institute *pay in cash* for certain publications—publications so unique and valuable that more than 350 folk in other countries have allied themselves with the Institute to receive them. For persons so located, however, many of the privileges of the Institute are necessarily out of reach. Our members in the United States and Canada should enjoy both the publications and the privileges. It is the special province of the Advisory Committee, of which I happen to be chairman momentarily, to aid and abet the membership in cultivating their privileges to a far greater extent than most of us have done.

The heading that stands at the beginning of each of these articles seems to me to catch up the essence of the matter. Dr. Johnson was a friendly man. He kept his eighteenth century friendships constantly renewed, and repaired, and replenished to the very end of seventy-five full years, even without the help of a *literary* Institute. How much easier is it today to accomplish this result! Opportunities for the constant repair of old friendships and the building of new ones are provided in the intimacies of committee work and in the general assembly at conventions. Behind each labelled lapel is a personality and an experience, different from yours, to be sure, and yet it may be, the perfect supplement to yours. Damon will not find his Pythias, Jonathan his David, on every trial (nor on every tenth trial) but is it not worth while to adventure into at least the more promising of these possibilities?

Dr. Johnson, through his perfect biographer, Boswell, has left an unusually complete and valued record of his philosophy and thoughts. He was a very human man. He often comments on the joy of self expression that may be realized through authorship. I would add the suggestion that authorship does not necessarily involve publication, nor are its benefits entirely denied to those whose early output the Editor rejects. No man in his first class room design of a concrete building would expect to excel the professional engineer and yet he may obtain both satisfaction and profit of it. Writing is a test of your mastery of a subject and of your ability to impart the essential facts and impressions to others. These things increase with practice. Your experience enriches your writing, your writing unifies and illuminates your experience. There is also an *obligation* to write. Are we free always to receive, always to borrow of other men's ideas and experiences—and never to return our personal contribution to the Institute's clearing house?*

To Dr. Johnson's famous remark I have, in the heading added an obvious extension. We are in the Institute because we are interested in concrete. Inevitably a committee man of the

*See Letter from I. J. Mair, Johannesburg, South Africa, in these pages. Mr. Mair finds privileges even in distance.—Editor.

Institute will acquire an enlarged store of facts. He will correct some, at least, of his own misapprehensions. If he be a constructor, he will gain much from his contact with the man from the laboratory who works to serve him. If he be an Engineer, he will widen his viewpoint from an inclusive discussion, and he will sharpen his wits by defending his opinions among his peers. To every man who spends his time, his interest (and his railroad fare) for active participation in committee work the dividends are important, quite apart from the repair of his friendships.

I wish to invite a more general participation in all these privileges of Institute membership. The Advisory Committee is looking for new helpers. It is very desirous of unloading the faithful headliners of many years' service or of putting them to work in new areas. It calls to mind an incident described in *Forbes Magazine* recently. Laborers were needed on a building and a feeble-minded but able-bodied man was employed to push a wheel barrow for the masons. After a bit, the foreman noticed this man trundling his wheel barrow back and forth to the hoist, but he had it always upside down. He explained to the foreman, "Every time I turn it over, some fool fills it up with bricks!" The Institute member, who keeps his wheel barrow upside down, save only when publications are handed out, might ponder this story. Why not carry a few bricks yourself for the structure that we are building in common? Why not help to keep our collective information in a state of constant repair?

"THE WORLD'S WORST AGGREGATE"—IN SOUTH AFRICA. A CHALLENGE

A LETTER FROM I. J. MAIR*

IN FORWARDING my subscription for my second year as a member of your society, I wish to let you know that despite my silence to date I fully appreciate that in my turn I must report on my own work to you good people and not be content merely to take what I can from others' papers.

In this somewhat distant part of the world I have found a very large field for research and experiment and although I have not come to any definite conclusions, I have collected considerable information.

At Johannesburg we are building a large railway station costing about three and a half million dollars (to put it in your money) and in the early stages of the work I convinced my principals of the need for better controlled concrete.

The writings of numerous Americans who have chosen to take up the same attitude show me that things are very much the same the world over. I certainly have not had an easy time. At present I have a small laboratory with a cement tension test machine and a 100 ton compression machine. To date I have had made 1750 6-in. cubes—largely routine testing of a 1:1:2 and a 1:2.4:4 concrete with ¾-in. stone as coarse aggregate and a modulus 3 sand as fine aggregate.

Here we have an enormous supply of quartzite from our gold mines. Contractors buy dumps of it broken to about 9 in. ring for $500 for 100,000 cubic yards. They retail it at about 75 cents per cubic yard crushed to

*C/o Chief Civil Engineer, South African Railway, Johannesburg.

various sizes. This aggregate must be the "world's worst" from a workability standpoint.* If you know of any previous records of its use on a large scale I should welcome the information. My main difficulty in using overseas data is that other people largely use gravel aggregate which is very different. In addition to the routine testing I frequently try out ideas of other people and myself for improving things and get surprising results.

The accounts of the annual conference make me wish I could visit your country. Perhaps this will be possible some day. In the meantime I shall continue to collect all the information I can regarding concrete work in this country to add my portion to the common store of knowledge.

Please send me some application forms for membership and I shall endeavor to get a few more members in these parts.

Many thanks for all that I have received from the Institute.

HUMANIZING TECHNICAL LITERATURE

A LETTER FROM J. C. PEARSON†

LET ME take this opportunity to say that I sincerely hope Mr. Lord will continue his series, "In Constant Repair." A lot of our technical reading would get much farther if we weren't all bound by tradition to eliminate every trace of levity and colloquialism from it. I wish somebody had the nerve and ability to write a technical article the way Harry Love tells a story. It would be shocking, of course, but I venture to say that the message would reach a lot more people. I don't mean that Lord's stuff is in any way comparable to Love's, but the idea of humanizing some of this technical discussion is not an impossible one, and the *News Letter* section is a place where it can be tried out. My opinion is that Lord's experiment is a great success, and I hope others like Nate Johnson and Professor Gilkey will contribute.

*This seems to be a challenge. Who has another entry as "the world's worst aggregate"? —EDITOR

†Ass't to Chemical Engineer, Lehigh Portland Cement Co.

MEET MR. ——

LOOK DOWN the list of new members in these pages—attracted by the efforts of the Institute to throw some light into obscure corners of its special field.

Then look through a mental list of your acquaintances, men who would really *count* in what the Institute is doing. Suggest to them the advantages of participation in Institute work, the advantages in what the Institute brings to them, significant in the field of their activity. There are three kinds of new members—those who give, those who take, those who give and take. They are all welcome. The "takers" may eventually take up the other function.

On just what basis the annual Honor Roll is to be continued is at this moment in question. To date (August 28) counting from Feb. 1 last, W. D. M. Allan is at the top. He has sponsored eight new members. Raymond E. Davis and F. R. McMillan share second place honors, each having sponsored six new members in the same period. J. C. Pearson is next with three new Institute members to his credit. Seven other members have each sponsored two and 49 others are responsible for one new member each.

NEW MEMBERS

SIXTY-NINE applicants for membership in May, June and July have been approved by the Board of Direction as follows:

MAY

DAVID C. COYLE, 101 Park Ave., New York, N. Y.

CRYSTAL ICE CO., Grafton, W. Va. (Jno. L. Hechmer, Pres.)

FRICK, WALTER H., 824 Rebecca Ave., Wilkinsburg, Pa.

GARITA, RICARDO CICERO, Varsovia 58, Mexico City, Mexico.

JOHNSON, A. W., 1908 Farwell Ave., Chicago, Ill.

JORSS, CHRIS A., c/o Telson Construction Co., Pty. Ltd., 34 William St., Melbourne, Victoria, Australia.

MCKAY, Richard T., 6629 Greenwood Ave., Chicago, Ill.

MATLIN, W. S., State Electrotechnical Trust, c/o I. G. E. Co., 1 River Rd., Schenectady, N. Y.

OAKLEY, T. D., Morgan Engineering Co., P. O. Box 1046, Harlingen, Texas

OVEREND, A. B., c/o H. Vivian Taylor, 499 Little Collins St., Melbourne, Australia.

PARDEE, CLARENCE G., 34 Remsen Lane, Floral Park, N. Y.

ROBESON, HAROLD B., c/o Nazareth Cement Co., Nazareth, Pa.

SMITH, JOHN WARD, Inspector, Pennsylvania Railroad, Philadelphia, Pa.

SOUTHERN KRAFT CORP., Panama City, Fla. (Erling Riis)

SOUTHWESTERN LABORATORIES, Box 1008, Ft. Worth, Tex. (F. B. Porter, Pres.)

WEAVER, H. A., Steel City Testing Laboratory, 8843 Livernois Ave., Detroit, Mich.

JUNE

BATES, HENRY K., Liverpool Artificial Stone Co., Ltd., Picton Rd., Wavertree, Liverpool, England

BENNETT, JOHN G., 2102 10th St., W., Calgary, Alta., Canada.

BINGHAM, GEORGE C., Sika Waterproofing Corp., 35 Grafton Ave., Newark, N. J.

BIRKLAND, GEORGE, 6054 Pershing Ave., St. Louis, Mo.

CAVANAGH, JR., W. CURRAN, Box 1454, Wenatchee, Wash.

CENTRAL CONCRETE MIXING CORP., 527 Smith St., Brooklyn, N. Y. (A. Johnson)

CLARK, KENNETH M., 3308 45th Ave., S., Minneapolis, Minn.

COFFMAN, HEBERT, Hercules Cement Corp., 1700 Walnut St., Philadelphia, Pa.

COTHRAN, F. H., Beauharnois Construction Co., Beauharnois, Que., Canada

DAVIS, HARMER E., Dept. of Civil Engineering, University of California, Berkeley, Calif.

DYKEMAN, HOWARD E., 3307 Washington Blvd., Cleveland Heights, Cleveland, Ohio.

FERNANDEZ, JUAN M., Director, Direccion de Bonos de Pavimentacion, Calle 11 No. 1204, La Plata, Argentina, S. A.

FREEMEN, E. M., 1208 City Bank Bldg., Shreveport, La.

GANNETT, J. K., The Austin Co., 120 Broadway, New York, N. Y.

HITCHINGS, A., 3520 Harford St., Seattle, Wash.

HOFFMAN, A. E., Gen. Mgr., Clinton Motors Corp., Reading, Pa.

KIMBERLY-CLARK CORP., Neenah, Wisconsin.

MUNSELL, J. R., Stone & Webster, Eldon, Mo.

RENSAA, E. M., Room 460, Union Station, Winnipeg, Man., Canada

ROSSER, ROBERT C., 296 Madison St. Wilkes-Barre, Pa.

SEXTON, JAMES E., S. S. Kresge Co., 2727 2nd Ave., Detroit, Mich.

SOC. ANONIMA IMPRESE GENERALI, Via Romagnosi No. 3, Milano, Italy

SOUTH CAROLINA HIGHWAY DEPT., Columbia, S. C. (W. H. Mills, Jr. Test. Engr.)

THEE, T. C., 864 Saunders Kennedy Bldg., Omaha, Nebr.

WARREN, RAY V., 406 Empire Bldg., Pittsburgh, Pa.

WERTZ CO., THE, 1033 Union Trust Bldg., Cleveland, Ohio

JULY

BETTS, CLIFFORD A., U. S. Reclamation Service, Owyhee, Oregon.

BINNEY & SMITH CO., 41 East 42nd St., New York, N. Y. (J. S. Kealy)

BOSTON BUILDING DEPARTMENT, 901 City Hall Annex, Boston, Mass. (Edw. W. Roemer, Commissioner)

BURGESS, L. T., Irrigation Bungalow, Bandarawella, Ceylon, India

CANADA CRUSHED STONE CORP., Sun Life Bldg., Hamilton, Ont., Canada

CINCINNATI BUILDERS, THE, 209 E. Sixth St., Cincinnati, Ohio (Julius J. Warner)

CLINTON METALLIC PAINT CO., Clinton N. Y. (John Mott, Vice Pres.)

COLORWAY, INC., 3800 S. Racine Ave., Chicago, Ill. (Marshall R. Rust)

DAILEY CONTRACTING CO., H. A., 434 Louderman Bldg., St. Louis, Mo.

ELLIS & SONS, LTD., JOHN, 16 Pocklingtons Walk, Leicester, England (Basil C. Sharman)

EMERSON CO., THE SAM W., 1836 Euclid Ave., Cleveland, Ohio. (R. E. Laubscher)

FERTELL, ARTHUR, c/o Raymond Concrete Pile Co., 140 Cedar St., New York, N. Y.

JAMESTOWN BLOCK & TILE CO., INC., Box 712, Jamestown, N. Y. (D. A. McClure, Treas.)

LARSON, D. E., 10208 S. Wood St., Chicago, Ill.

LAWSON, DAVID, 793 Broadway, New York, N. Y.

MAGNY, A. V., Plateau St. Hilaire, Grasse A. M., France

MINNESOTA HIGHWAY DEPT., Exp. Engineering Bldg., University of Minnesota, Minneapolis, Minn. (F. C. Lang)

MURPHY, GLENN, 201 Engineering Bldg. No. 1, University of Colorado, Boulder, Colo.

NELSON, NORMAN, Y. M. C. A. Elm & Central Pkwy., Cincinnati, Ohio.

NEWCOMB, REXFORD, University of Illinois, 118 Architecture Bldg., Urbana Ill.

PERKINS, WAYNE A., 3102 Montgomery Way, Sacramento, Calif.

PRACK, BERNARD H., 119 Federal St., Pittsburgh, Pa.

SIDDIQUE, BASHIE AHMAD, Cho. A. K. Nawahzade Esq., 18 Rajpur Road., Delhi, India.

SMALLHORN, E. R., The Aerocrete Construction Co., Basin & Seigneurs Sts., Montreal, Que., Canada

TOLEDO CONCRETE PIPE CO., P. O. Box 835, Toledo, Ohio (L. J. Loughlin)

WILLIAMS, TIMOTHY S., 3707 Hamilton St., Philadelphia, Pa.

WOLFE, W. S., 800 Marquette Bldg., Detroit, Mich.

REINFORCED CONCRETE COLUMN TEST FUND

Cash previously acknowledged (See April JOURNAL)	$11,102.50
Material donations previously acknowledged.....	975.19
	$12,077.69
Received since publication of April Journal:	
Aberthaw Co., Boston—cash	100.00
Kalman Steel Co., Chicago—Reinforcing steel & freight	196.00
Truscon Steel Co., Youngstown, O. — Reinforcing steel & freight.....	202.39
Rail Steel Bar Assn., Chicago (Franklin Steel Co.)—Reinforcing steel & freight	205.10
Concrete Steel Co., New York—Reinforcing Steel & freight.....	203.21
Illinois Sand & Gravel Assn. sand, gravel and freight..	195.14
To Date.....	$13,269.53

Papers and Reports—In this Issue

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Publication of discussion of the contributions in the following pages is on a time schedule. Please see inside cover pages.

Memorandum On Arch Dam Developments

BY LARS JORGENSEN*

SYNOPSIS

The intention in the presentation of this paper is to record some of the recent developments in arch dam design and construction in general and in Constant Angle Arch Dam design in particular.

The work described covers the period of the last 16 years. During this period more arch dams have been built than ever before and their design has finally been developed upon as scientific a foundation as that of any other type of dam.

The possibility of obtaining a high factor of safety economically is beginning to become generally recognized by the profession. This was not so 16 years ago.

Actual cost data have been given for the various structures described—covering all kinds of locations—in order to have reliable figures available as a guide for estimating the cost of new work.

Arch Dams can not be called new and untried any longer since the highest dams built and being built are now of that type.

As time goes by, the art of dam building is improving along with other lines of activities. Faith in arch dams is beginning to manifest itself among engineers, especially among the younger set; and the preference shown by many engineers for gravity dams is beginning to give place to a desire for a more economical structure such as an arch dam on sites where this type fits.

An engineering structure must first of all be safe, and secondly it should be economical. It does not require much skill merely to use plenty of material in a structure in order to make it safe; the material should always be placed where it does the most good. The factor of safety may properly vary on various structures, depending upon their importance, but this does not alter the fact

*Consulting Hydro-Electric Engineer, San Francisco.

that whatever material is used, it should be placed as economically as possible.

In a gravity dam it is not possible to utilize the material to the best advantage; half of it is not fully working with reservoir full. Nevertheless, there are cases where this type still remains the best type to use.

In the past, gravity dams have been almost exclusively built on large important projects. At present, however, the arch dam theory has been developed to a stage where it is possible to predetermine the stresses in such a structure with a satisfactory degree of dependability, and with as great accuracy as the stresses in a gravity dam near the foundation. There is no more uncertainty about the behavior of an arch dam than about most any other structure. Enough arch dams have been built and are building to inspire confidence that the principle is right. About the only mystery about arch dams is that no single arch dam has ever failed; there are several freaks existing, almost mysteriously holding a reservoir full of water. (Crowley Creek, Bear Valley Upper Otay.)

Professor Cain put the calculation of arch dams on a better technical basis than it had been before the appearance of his paper "The Circular Arch Under Normal Load."* If his method of calculation is followed, using conservative stresses, a structure of definite safety will result. The lower the stresses are assumed naturally the higher the factor of safety will be. How high it should be depends, as already stated, upon the importance of the work.

Professor Cain's theory as well as the work of Jakobsen, Noetzli and others is to a great extent responsible for the conversion of many members of the profession from being blind gravity enthusiasts to arch dam considerers or even to arch proponents.

There is hardly a subject to be found in engineering where two factions of engineers have been opposed to one another so definitely, as on the subject of gravity dams versus arch dams. On sites where arch dams do not fit, of course, they have no place. In this connection, the words "do not fit" mean where they are not safer and cheaper.

The fact that no single arch dam has ever failed and that to the

*Trans. Am. Soc. Civil Engineers, 1922, page 233.

writer's knowledge 25 gravity dams have failed from one cause or another (19 during the last 30 years),† should be convincing proof that even the most conservative engineers cannot afford to overlook the possibility of the arch dam. The engineer is responsible to his client and should give him the best for his money, regardless of the inconvenience it may cause the engineer to investigate a field new to him.

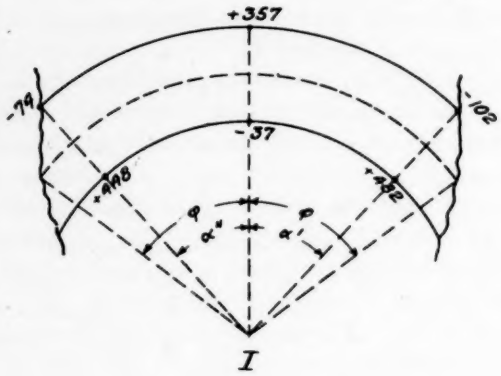
To choose a gravity dam in any and all cases merely because the engineer has been an advocate of this type of dam all his life is a poor foundation for a choice. A decision should be based upon the results of calculations of safety and cost of structure, and not upon preconceived or inherited ideas.

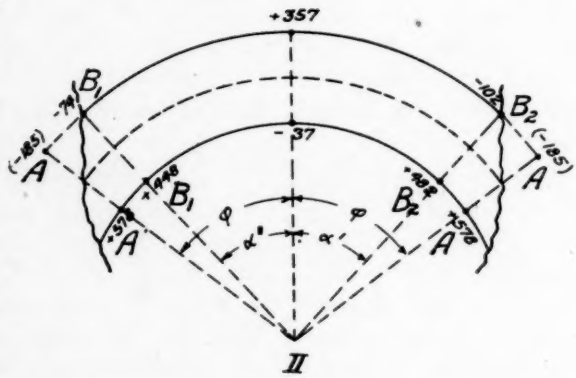
It has been mentioned above that Cain's formulas for a fixed arch under normal load can be regarded as standard; they are now used in design work done by the Constant Angle Arch Dam Co., San Francisco, with which the writer is connected. Some difference of opinion may exist as to how to apply the formulas in cases where the rock abutments are not radial, and such cases are common.

The three sketches, Figures 1, 2 and 3, illustrate various assumptions possible as to span, length, subtended angle, etc., when the abutments are not radial. When calculating the bending moment at the crown the subtended angle of $2\,\phi$ is used in Fig. 1. This angle subtends the points of intersection of the middle line with the abutments. The middle line is assumed to be equal and generally is equal to the average length of the arch, subject to the elastic deformation. The plane of maximum bending moment is taken to be where a radial line first intersects the rock abutments, either on the up or downstream face, as the case may be. Here the water load is assumed to stop on the arch proper. When calculating the maximum bending moment here the smaller value $2\,\alpha$ is used for the subtended angle.

For a thick arch, additional calculations are made assuming the maximum plane of bending to be along the plane A-A, Fig. 2, being a radial plane through the point of intersection of the center line or middle line of the arch ring with the rock abutment. The subtended angle $2\,\phi$ is used for the calculation of the bending

†See "Record of 100 Dam Failures," by Lars Jorgensen, Journal of Electricity, San Francisco, March 15, April 1, 1920.





FIGS. 1 AND 2—PACIOMA DAM. STRESSES IN POUNDS PER SQUARE INCH, ELEVATION 1825

moments both at the crown and at the abutments, A-A in this case.

This gives a check on unit compression at the downstream face in plane A-A. If found too high, the dimension should be increased. No attention is paid to possible tension in the rock along the continuation of the upstream face, as none can actually exist.

In Fig. 3, the third possible assumption as to the location of the planes of maximum bending moments and value of subtended angle 2 ϕ is shown. Here the same subtended angle 2 ϕ is used

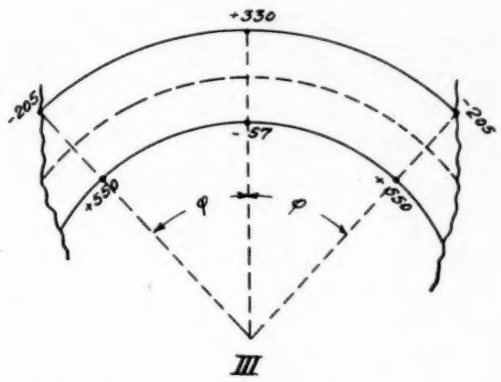


FIG. 3—PACOIMA DAM. STRESSES IN POUNDS PER SQUARE INCH, ELEVATION 1825

for the calculation of both the bending moments at the crown and at the abutments. The influence of using a smaller subtended angle on these bending moments is to the effect of generally lowering the stresses at the crown, at least at the upstream face, and increasing them at the abutments. The stresses at the abutments practically always control the design. On important work it may be well to use all three variations for checking purposes.

When making a design for an arch dam, the simple arch formula (*unit water pressure* $\times$ *length of upstream radius* = *unit stress* $\times$ *thickness*) can most conveniently be used in order to obtain a preliminary section. Then the bending moments and resulting stresses are calculated by means of Cain's formulas. Since the bending moments at the abutments are approximately twice as high as the bending moment at the crown, the thickness at the abutments will not be the same as the thickness at the crown, but will have to be increased towards the abutments to correspond to the increase in stress due to the effect of the larger bending moment. This increase in thickness should commence at a point located between 15 and 18 per cent of the length of the arch out from each abutment. The addition of material should be placed mostly on the downstream face and should increase in thickness from 0 at $\frac{15}{100}$ to $\frac{18}{100}$ of length of arc from the abutments, to a maximum at the abutments.

TABLE TO ACCOMPANY FIGURES 1, 2 AND 3

			Elev. 1825 I	Elev. 1825 II	Elev. 1825 III
t_o thickness of dam at crown		ft.	51.0	51.0	51.0
t_1 thickness of dam at abutment		ft.	51.0	51.0	51.0
R_s		ft.	160.0	160.0	160.0
$r = R_s - \frac{t_o}{2}$		ft.	134.5	134.5	134.5
r_2		ft.^{2}	18090	18090	18090
$2\phi^\circ$			95.0°	95.0°	85.5°
ϕ°			47.5°	47.5°	42.75°
$\phi = \phi^\circ \times \frac{\pi}{180} = \phi \times 0.01745$			0.82888	0.82888	0.74599
$\sin 2\phi$			0.99619	0.99619	0.99692
$\sin \phi$			0.73728	0.73728	0.67880
$\cos \phi$			0.67559	0.67559	0.73432
$\frac{\sin \phi}{\phi}$			0.88949	0.88949	0.90993
$1 - \frac{\sin \phi}{\phi}$			0.11051	0.11051	0.09007
α'	(right abutment)		43.5°	43.5°	—
α''	(left abutment)		42.0°	42.0°	—
$\cos \alpha'$			0.72537	0.72537	—
$\cos \alpha''$			0.74314	0.74314	—
$k^2 = \frac{1}{12} \times t_o^2$			216.75	216.75	216.75
$D = \left(1 + \frac{k^2}{r^2}\right) \times \phi \times (\phi + \frac{1}{2} \sin 2\phi) - 2 \sin^2 \phi$			0.02594	0.02594	0.01794
$D' = D + 2.88 \times \frac{k^2}{r^2} \times \phi \times (\phi - \frac{1}{2} \sin 2\phi)$			0.03540	0.03540	0.02431
$\frac{D}{D'}$			0.7328	0.7328	0.7380
$\frac{2 \sin \phi}{D'}$			41.654	41.654	55.845
p lbs. pr. sq. ft.			12,500	12,500	12,500
$p_1 = p \times \frac{R_s}{r}$ lbs. pr. sq. ft.			14,870	14,870	14,870
$p_1{}^r$			2,000,000	2,000,000	2,000,000
$(p_1{}^r - P_o)^s = 2\frac{\sin}{D'} \phi \times p_1 \times \phi \times \frac{k^2}{r}$			827,363	827,363	998,309
Crown	$P_o{}^s$	lbs.	1,172,637	1,172,637	1,001,691
	$M_o{}^s = -(p_1{}^r - P_o)^s \times r \times \left(1 - \frac{\sin \phi}{\phi}\right)$	lbs. ft.	12,297,588	12,297,588	12,093,930
Abutment I	$P_1{}^s = p_1{}^r - (p_1{}^r - P_o)^s \cos \alpha'$ (right abutment)	lbs.	1,399,856	—	—
	$M_1{}^s = (p_1{}^r - P_o)^s \times r \times \left(\frac{\sin \phi}{\phi} - \cos \alpha'\right)$ (right abutment)	lbs. ft.	18,263,326	—	—
	$P_1{}^s = p_1{}^r - (p_1{}^r - P_o)^s \cos \alpha''$ (left abutment)	lbs.	1,385,153	—	—
	$M_1{}^s = (p_1{}^r - P_o)^s \times r \left(\frac{\sin \phi}{\phi} - \cos \alpha''\right)$ (left abutment)	lbs. ft.	16,285,875	—	—
Abutment II	$P_1{}^s = p_1{}^r - (p_1{}^r - P_o)^s \cos \phi$	lbs.	—	1,441,042	—
	$M_1{}^s = (p_1{}^r - P_o)^s \times r \times \left(\frac{\sin \phi}{\phi} - \cos \phi\right)$	lbs. ft.	—	23,802,861	—
Abutment III	$P_1{}^s = p_1{}^r - (p_1{}^r - P_o)^s \cos \phi$	lbs.	—	—	1,266,922
	$M_1{}^s = (p_1 r - P_o)^s \times r \times \left(\frac{\sin \phi}{\phi} - \cos \phi\right)$	lbs. ft.	—	—	23,579,604

STRESSES IN LBS. PER SQ. INCH, ELEV. 1825

Towards the crest of the dam where excess material is used to provide for a practical thickness the up and downstream faces can be kept concentric. Towards the bottom the shear action predominates, especially in narrow canyons, and the dam is to be investigated for this action in its lower portion.

ALLOWABLE STRESSES

When calculating the bending moments and resulting stresses on actual structures, as shown later, the normal load on the structure is taken to equal the full water pressure; the portion of the water load taken by the cantilever has been neglected. To find the portion of load taken by the cantilever is a difficult problem; the amount taken in the middle of the canyon differs from the amount taken at other points and due to the effect of water soaking the cantilever may not take any load. Therefore, this action has been neglected, which is on the side of safety.

Before deciding upon the maximum stress to use, the ultimate strength of the concrete must be determined and the importance of the structure considered.

The writer first used a concrete mix which would have a crushing strength of 1500 to 2000 lbs. per sq. in. when 28 days old. Recently only the upper limit and above has been considered. The amount of cement is varied in such a manner as to give this strength when mixed with the aggregate at hand at the different locations. Less than a barrel of cement to the cubic yard is never used and more than a barrel of cement per cubic yard of concrete often has to be used in order to bring the strength and water-tightness up to the desired standard. The cement is the only thing that glues the particles together and makes the dam a watertight monolith and to save to the limit on cement is not good economy.

When calculating stresses in accordance with assumptions shown in Fig. 1 on work of average importance a maximum compression of 600 lb. per sq. in. and a maximum tension of 100 lb. per sq. in. are generally used. Maximum tension should not be paired with maximum compression, as in case the dam should crack in the tension side and thereby relieve the tension, more compression may be thrown on the compression side, although not always.

Sometimes a crack in the tension side (relieving the tension) may also relieve the compression on the compression side, depending upon whether the bending moment is created by a large force acting through a small eccentricity or by a small force acting through a large eccentricity. Whenever a large compression exists at the downstream face at the abutments it is safer not to allow a large tension at the upstream side of the abutments. If such a combination should happen, the thickness of the arch ought to be increased. The abutment stresses are the controlling stresses, as here the bending moment is the greatest.

If the simple arch formula were used in order to obtain a preliminary section using between 300 and 350 lbs. per sq. in. for the arch compression, it will generally be found that the section will be ample at the crown and that additions to the thickness only need be made at the abutments in order to satisfy the Cain formulas using the extreme stresses up to 600 lb. compression and 100 lb. tension per sq. in.

Should the assumption shown in Fig. 3 be used, it would be safe to allow somewhat higher unit stresses, since the condition represented by it is more severe than actually is the case.

Even using the assumptions shown in Figures 1 and 2 will indicate higher stresses than actually exist, for several reasons:

1. The cantilever action perhaps takes some of the load.

2. The concrete especially near the upstream face is wet and expands, relieving the tension.

3. In case the stresses are very high (higher than 800 lb. per sq. in. compression) a redistribution may take place due to the action of the time factor in creating "flow."

4. The arch may not be fixed in an extreme sense, hence taken all in all, the assumed designing stresses (600 lb. per sq. in. compression and 100 lb. per sq. in. tension) will not materialize at the abutments where the stresses generally are the highest.

A factor of safety of between 4 and 5 for the structure should therefore be a reality.

During the last 16 years, 40 or more Constant Angle Arch Dams have been built, besides many ordinary arch dams. Several large Constant Angle Arch Dams are being constructed at present, and this type of dam can therefore hardly be called

new and experimental any longer. The Constant Angle Arch design has been previously explained* and a detailed description of two large arch dams—the Lake Spaulding Dam, (California) and the Salmon Lake Dam, (Alaska) given.

Since then improvements in the design of arch dams have been effected partly due to practical experience gained in building numerous dams and partly due to improvements in the theory as recently advanced by different writers on the subject.

In the following the description of several typical Constant Angle Arch Dams recently built will be given indicating the successive improvement in design.

FIG. 4A—BULLARDS BAR DAM UNDER CONSTRUCTION. HEIGHT 183 FT. ABOVE FOUNDATION; SPAN 440 FT.

Figures 4, 5, 5A and 5B show working details of the Bullards Bar Dam built on the North Fork of the Yuba River, California. This dam is 182 ft. high above the foundation (175 ft. above river level) and creates a head of 175 ft. which is utilized in a power

*Trans. Am. Soc. C. E., 1915, v. 78, p. 685.

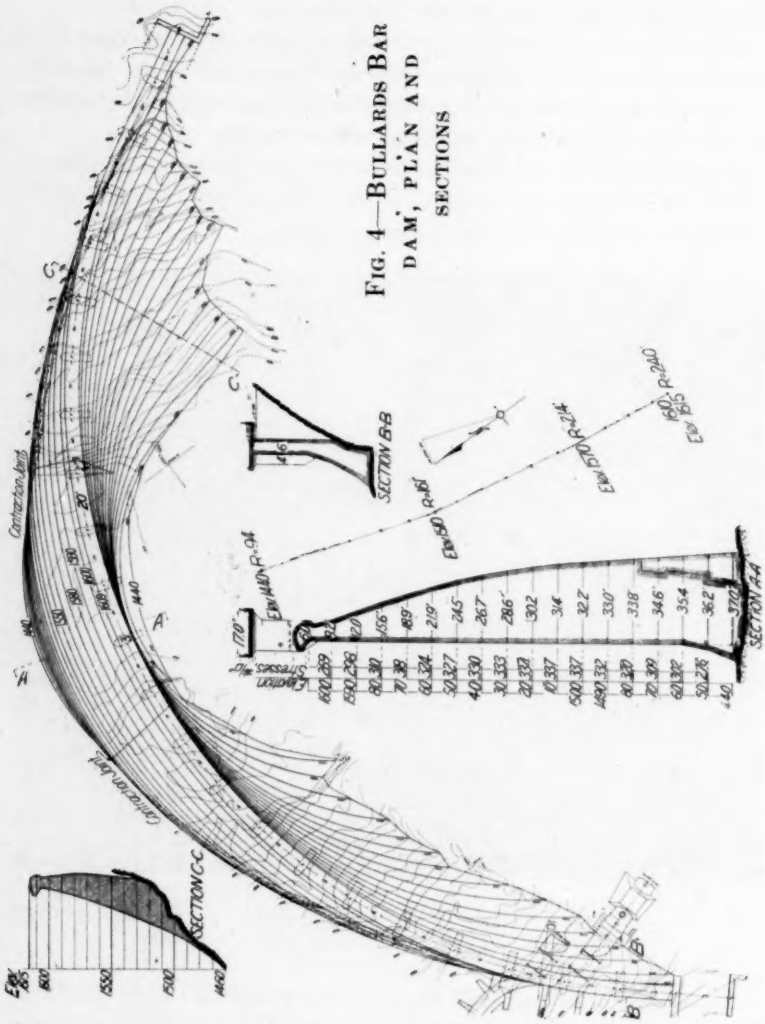


FIG. 4—BULLARDS BAR DAM, PLAN AND SECTIONS

plant located 300 ft. below the dam. The length of the upstream radius varies from 240 ft. at the crest to 94 ft. at the bottom. The development is now operated as part of the Pacific Gas & Electric Company's system. The reservoir space created by this dam is principally to be used for storing debris from gold mines located on the drainage above. Hydraulic gold mining was discontinued on a large scale in the early eighties when dumping of gravel or debris into any tributary to the Sacramento or San Joaquin Rivers was prohibited because these rivers were being rapidly filled up with gravel from the mines. With reservoirs built on the tributaries for storing this gravel, hydraulic mining is again legally possible.

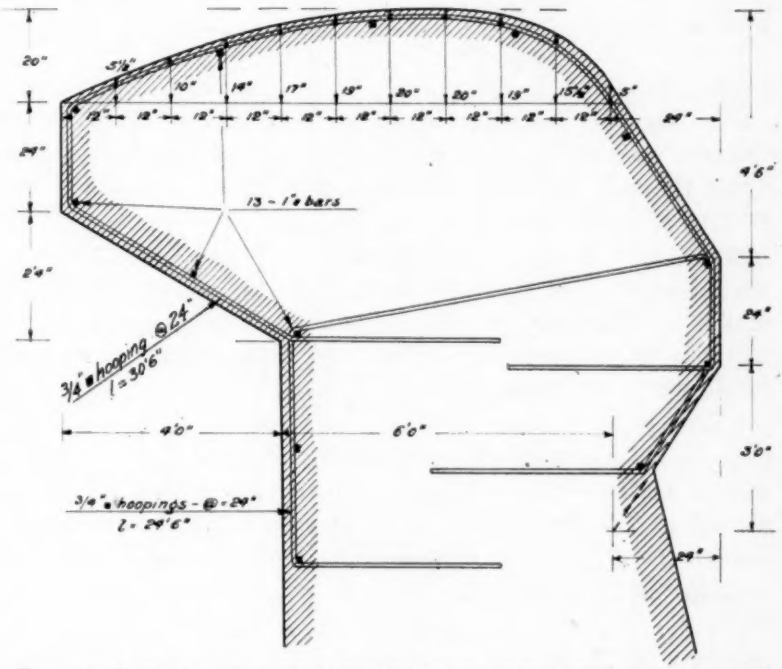


FIG. 5—SECTION THROUGH SPILLWAY LIP, BULLARDS BAR PROJECT

The Bullards Bar reservoir will store approximately 70 million cu. yds. of debris to within 15 ft. of its crest. This represents also the approximate yardage of gold bearing gravel still remaining to be worked by the hydraulic method above this dam.

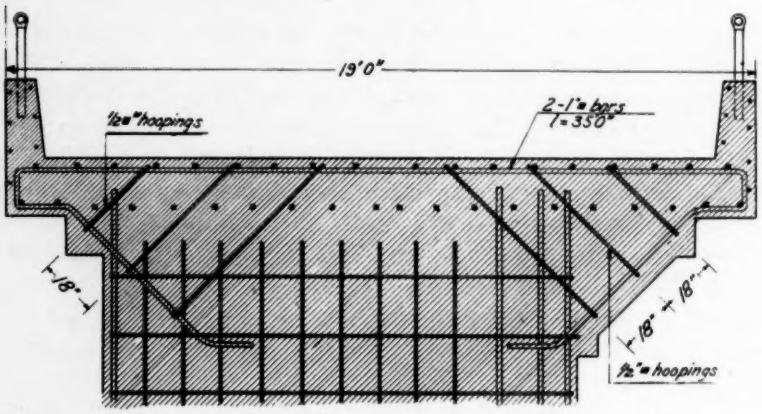


FIG. 5A—SECTION THROUGH ROADWAY, BULLARDS BAR PROJECT

Filling the reservoir with gravel and sand will not seriously interfere with the development of power, and since this dam is designed for a 13 ft. overflow it can be provided with 13-ft. gates along the crest whereby the fluctuating water storage will be increased by 8,000 acre ft.

This dam is designed to pass 65,000 sec. ft. over the crest. The normal winter flow, which is much less, requires only the three middle openings and it is intended to keep the tainter gates along the crest closed except a few in the middle in order to keep the head up to a maximum.

The dam has been in operation four winters without tainter gates and considerable experience has been obtained from watching the action of the overflow. The overflow period has been about 6 months every year, and the greatest depth of water going over the crest has so far been 11 ft. equivalent to 50,000 sec. ft.

In the middle of the dam the sheet of falling water stays clear of the dam and falls on a loose rock fill, if considerable water is flowing a pool is formed automatically.

On the sides however, the water first leaves the crest and then later strikes the concrete lower down under a small angle and finally strikes the rough rock abutment which is very solid.

In the middle no wear and tear can be detected. On the sides there is some wear of the concrete where the water strikes the

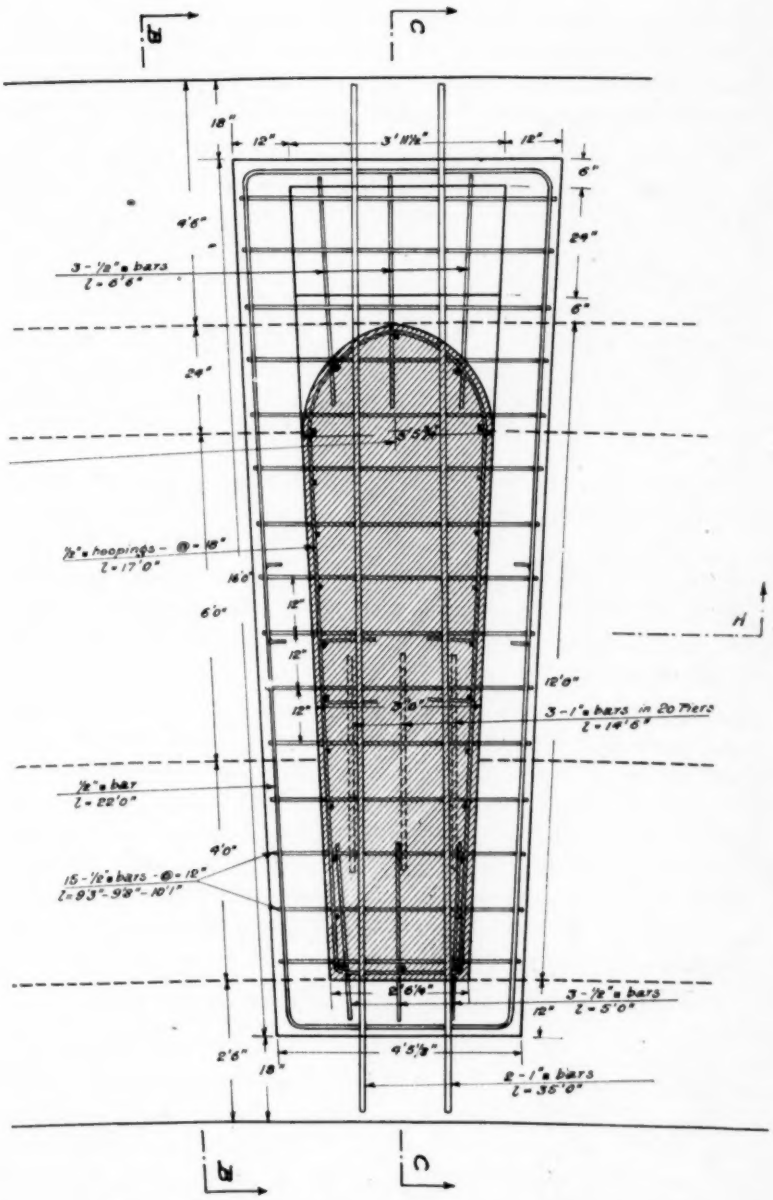


FIG. 5B—PLAN OF PIER, BULLARDS BAR PROJECT

dam body under a small angle. The wear on the rock is considerable however, and in order to prevent further wear tainter gates are now being installed on the sides to prevent the spill from going over the crest at that point and to confine it to the middle portion of the dam where no wear takes place.

In a river which is fairly level the writer has found that a mat of loose rocks (from the excavation) is a very safe bed for the overflow to fall on. The sheet of water striking the fill will split into many little jets whereby the energy will quickly be destroyed. The mat should be about 15 ft. thick under a fall of over 150 ft. During the first overflow period the mat will become two to three feet thinner where the water strikes it due to the pounding it receives, and after that nothing except dynamite can remove the rock.

On the Bullards Bar project a small dam for the purpose of forming a pool and for holding the rock fill back was provided. The secondary dam was about 5 ft. high and was completely buried in the rockfill. The rockfill stayed in place below the dam just as well as above, showing a secondary dam was unnecessary, and none has been provided on 14 free, overflow arch dams with which the writer has been connected.

For calculating the stresses in the dam, the assumption has been made that the reservoir was full of debris to within 15 ft. from the crest with 28 ft. of water on top of the debris. The weight of the debris was taken to equal 90 lb. per cu. ft. A reinforced concrete bridge along the crest of the dam takes the main county road across the canyon. This bridge has been designed for two 15-ton trucks meeting each other on the 20 ft. spans. A small forebay on the west side keeps the debris away from the pressure pipe intake.

The contraction joints are provided with a grout pipe system.

This dam was let by contract to the lowest bidder, Bent Bros., Inc., Los Angeles, and the following are the unit prices paid them on the main items:

Loose dirt excavation—2,500 cu. yd.	@	$ 2.50
Loose rock excavation—2,000 cu. yd.	@	2.50
Solid rock excavation—1,000 cu. yd.	@	5.00
Plain 1:3:6 concrete not including the cement—46,000 cu. yd.	@	6.45

Reinforced concrete 1:2:4 not including the cement—1,800 cu. yd.	@	$19.00
Installation of grout pipes	per ft.	1.00
Cement grouting—50 sacks	@	2.00

The dam is located 40 miles from the nearest railroad station at Marysville, California.

Very good concrete material in the form of river gravel was found in sufficient quantity 1¼ miles from the dam. This gravel was screened and remixed in the proper proportion for maximum density, using 2½-in. rock as the maximum size for best grading. Rocks up to 6 in. were left in the mix, but there were too few for complete grading. The actual mix was, most of the time, 1:2.8:6.5. The mixing plant was located high up on the hillside and the concrete was deposited by gravity through a chuting system of the Insley type. The sand (1:3 mortar) tested 12 per cent better than standard Ottawa sand in tension and 25 per cent better in compression at all ages.

Cylinders of concrete, 8 in. diameter and 16 in. long, were tested regularly, as the construction progressed, at the age of about 30 days. A test result (the average of six cylinders) picked out at random reads: 1673 lb. per sq. in. when 28 days old (Sept. 11th, 1923). The specimens were taken from the concrete in the dam. When fully aged this concrete can be expected to develop a crushing strength around 3000 lb. per sq. in. The weight per cu. ft. was 150 lb. The design of this dam, was made by A. C. Hoff, chief designing engineer for the Constant Angle Arch Dam Co. The testing was in charge of Theodore P. Dresser, Jr., chief engineer of Abbot A. Hanks, Inc., San Francisco, who also was in charge of testing on several of the dams mentioned later. George Ray was resident engineer and B. T. Millard his assistant engineer.

The constant angle arch dam which will pass a great amount of overflow over its crest is the Kerckhoff dam on the San Joaquin River, California, described by B. F. Jakobsen.* The tainter gates are 14 ft high. With a water level 14 ft. above the crest 60,000 sec. ft. will flow over the crest, and 100,000 sec. ft. can go over without interfering with the bridge on top. This dam has been in use for the last ten years. The overflow takes place about four to five months every year. It falls upon a loose rockfill made from the excavation and there is no secondary

*Trans. Am. Soc. C. E., 1921, Vol. 84, p. 105-107.

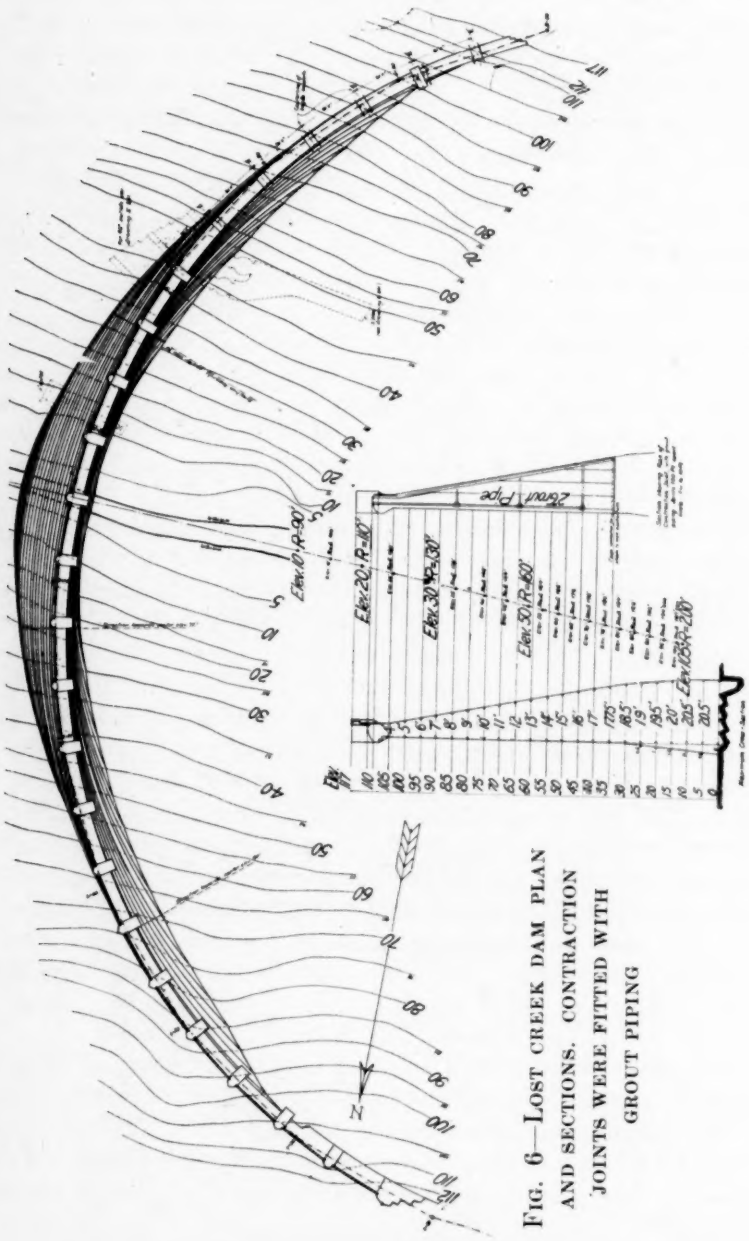


FIG. 6—LOST CREEK DAM PLAN AND SECTIONS. CONTRACTION JOINTS WERE FITTED WITH GROUT PIPING

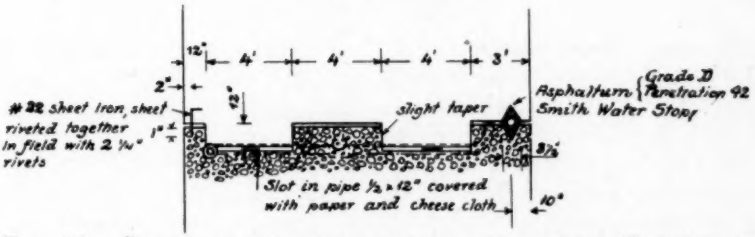


FIG. 6A—SECTION LOST CREEK DAM AT ELEVATION 45 SHOWING GROUT PIPES AND WATER STOP

dam. The Aluminum Co. of America has just fiinished a Constant Angle Arch Dam on the Little Tennessee River 180 ft. high, designed for 200,000 sec. ft. of overflow.

In Figures 6 and 6A, an arch dam 112 ft. high is shown in detail, having a variation in the length of its upstream radius of from 200 ft. at the top to 90 ft. at the bottom. It stores water for the Oroville-Wyandotte Irrigation District, of which S. J. Norris was chief engineer. F. E. Baxter was resident engineer.

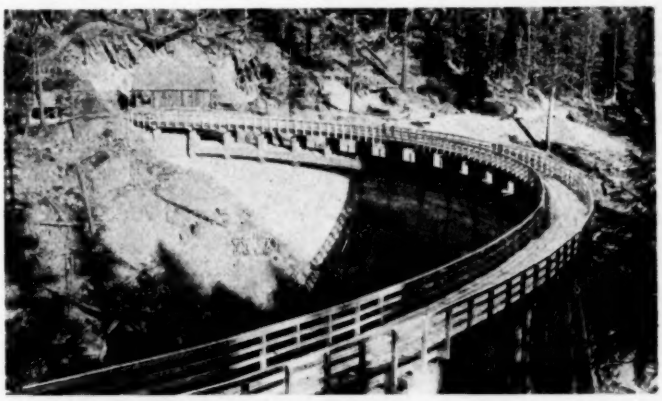


FIG. 6B—LOST CREEK DAM, 112 FT. HIGH, 380 FT. SPAN. THICKNESS AT CREST 4 FT.; AT BOTTOM 235 FT.

It is seen that the canyon is well adapted to a Constant Angle Arch type of dam, being of a quite regular "V" shape. All the centers lie on a straight line which makes it easy to lay out the dam. A wooden bridge on piers along the crest accommodates an unimportant county road. The contraction joints are provided with grout pipes and Smith patented waterstop.

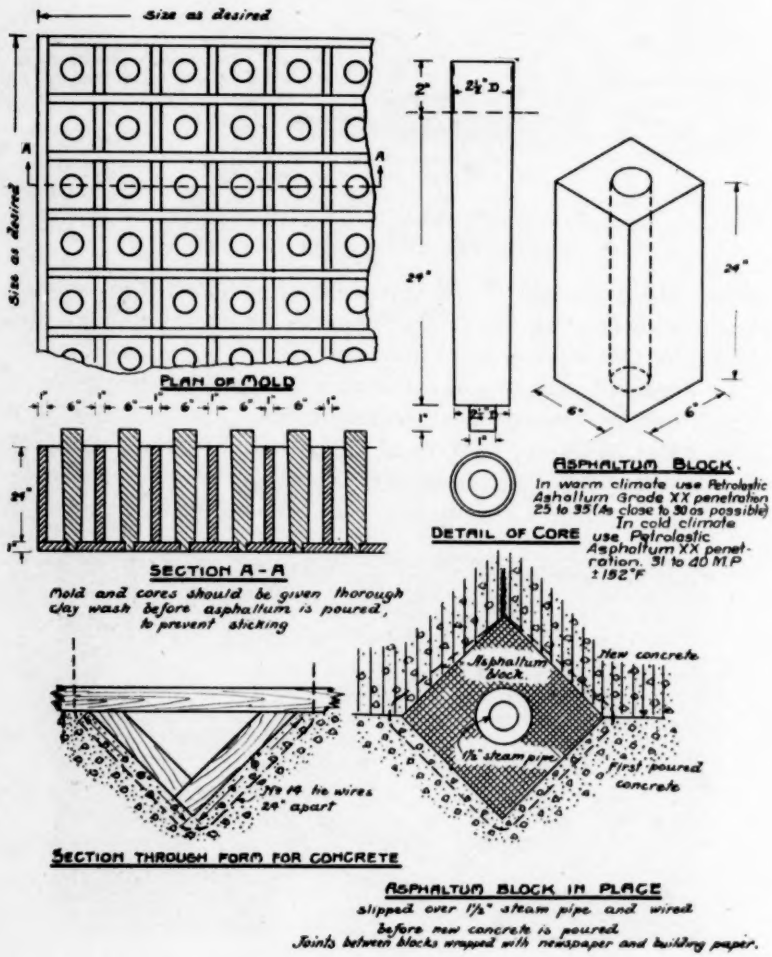

Size as desired
Size as desired
PLAN OF MOLD
SECTION A-A
Mold and cores should be given thorough clay wash before asphaltum is poured, to prevent sticking
2"
2½"D
24"
1"
2½"
ASPHALTUM BLOCK.
In warm climate use Petrolastic Asphaltum Grade XX penetration 25 to 35 (As close to 30 as possible)
In cold climate use Petrolastic Asphaltum XX penetration. 31 to 40 M.P. ±192°F
DETAIL OF CORE
Asphaltum block
New concrete
1½" steam pipe
First poured concrete
No 14 tie wires 24" apart
SECTION THROUGH FORM FOR CONCRETE
ASPHALTUM BLOCK IN PLACE
slipped over 1½" steam pipe and wired before new concrete is poured.
Joints between blocks wrapped with newspaper and building paper.

FIG. 7—DETAILS OF SMITH WATER STOP

A detail of the Smith waterstop is shown on Fig. 7. It consists of precast asphaltum blocks strung on an iron pipe and built in across the contraction joints close to the upstream face. The asphaltum may also be poured in around the pipe in say, 5 ft. lifts. Later steam is let through the pipe and the blocks melt

together and fill the diamond shaped hole and any cavity which may exist. This waterstop was first brought out by Francis B. Smith, member, American Society Civil Engineers.

The dam is an overflow dam provided with flashboards 3 ft. high. The normal overflow is confined by means of these flash boards to the middle portion where it falls clear of the dam. With 5 ft. of water going over the entire crest the discharge is 15,000 sec. ft. The dam was built by contract, Messrs. Lord and Bishop of Napa, California, being low bidders and being awarded the contract at the following unit prices on the main items:

570 cu. yd. of loose rock and gravel excavation	@	$ 1.25
2378 cu. yd. of solid rock excavation	@	5.00
11,093 cu. yd. of 1:3:6 concrete, including everything except the cement	@	5.15

The dam is located in rough country, 50 miles from the nearest railroad. The concrete material was found within a mile of the dam and consisted of gravel, which was screened and remixed in the proper proportion. When the work was half completed the

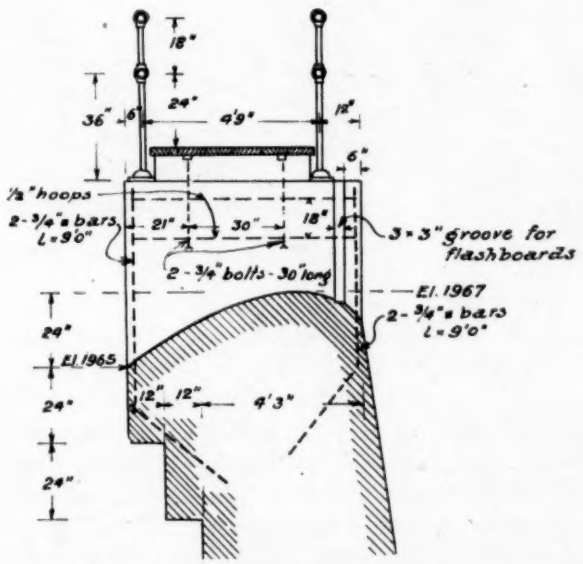


FIG. 8A—CONCOW DAM SECTION OF SPILLWAY AND BRIDGE

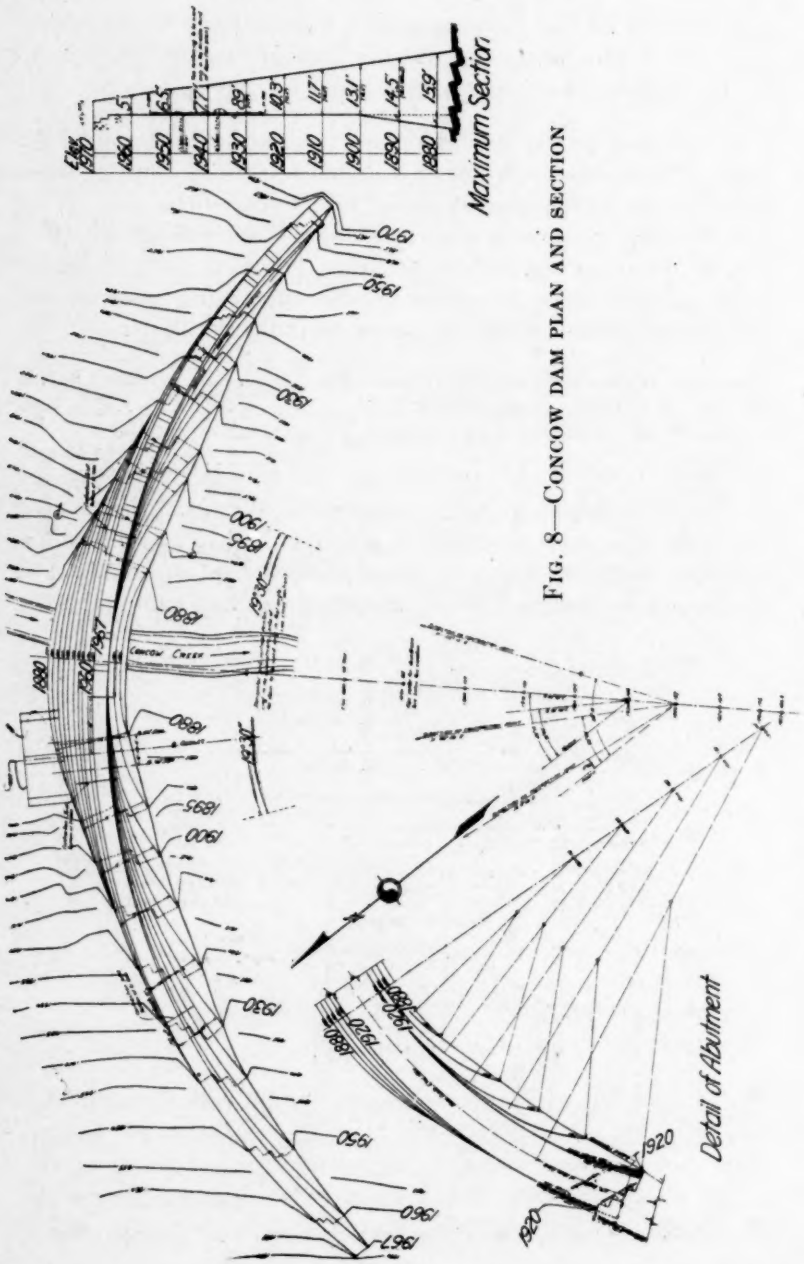


FIG. 8—CONCOW DAM PLAN AND SECTION

deposit became deficient in coarse material. A quarry was then opened up and crushed rock was mixed with the gravel.

The larger sand particles were slightly weak, but the average quality of the sand particles was satisfactory. The sand (1:3 mortar) gave low seven-day strengths (tensile 82 per cent and compression 68 per cent of standard Ottawa sand), but had high 7-day to 28-day gains, giving 28-day tensile and compressive strength 100 per cent and 92.5 per cent respectively of standard Ottawa sand.

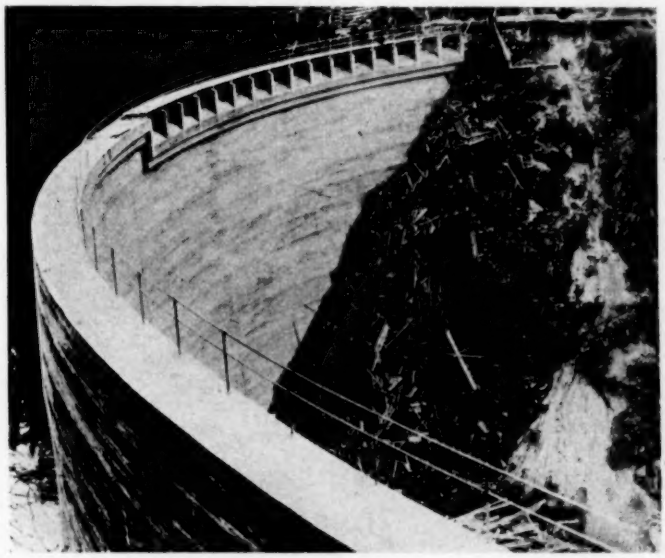


FIG. 8B—CONCOW DAM, 90 FT. HIGH ABOVE STREAM BED. SPAN 275 FT.

Somewhat over 1 barrel (average addition 15 per cent) of cement per cubic yard was necessary to bring the crushing strength of the concrete up to 1500 lb. per sq. in. when 28 days old. Ultimately, this concrete should develop a strength of at least 2500 lb. per sq. in. The concrete was graded to a maximum size of 3 in.; it was mixed for 1¼ minutes after all the ingredients were deposited in the mixer and distributed through a chuting system of the Insley type. This design and also the design of the Bullards Bar dam was made using the simple arch formula.

TABLE TO ACCOMPANY FIG. 9

Numbers refer to formulas as given by Wm. Cain in paper No. 1483, Transact. A.S.C.E., 1922.		Dam—Crest Elev. 1967					Dam—Crest Elev. 1947		
		Elev. 1890	Elev. 1900	Elev. 1910	Elev. 1920	Elev. 1930	Elev. 1890	Elev. 1900	Elev. 1910
	t_1	16.0′	13.1′	11.7′	10.3′	8.9′	12.5′	9.6′	8.2′
	t_2	18.0′	16.0′	15.0′	13.5′	11.7′	13.0′	10.5′	9.5′
	R_u	92′	107′	121′	134	146′	92′	107′	121′
	$r = R_u - \frac{t_1}{2}$	84.0′	100.4′	115.15′	128.85	141.55′	85.75′	102.2′	116.9′
	$2\,\phi°$	64°	68°	73°	79°	83°	64°	68°	73°
	$\phi°$	32°	34°	36.5°	39.5°	41.5°	32°	34°	36.5°
	$\phi = \phi° \times \frac{\pi}{180} = \phi \times 0.01745$	0.55840	0.59330	0.63693	0.68928	0.72418	0.55840	0.59330	0.63693
	$\sin 2\,\phi$	0.89879	0.92718	0.95630	0.98163	0.99255	0.89879	0.92718	0.95630
	$\sin \phi$	0.52992	0.55919	0.59482	0.63608	0.66262	0.52992	0.55919	0.59482
	$\cos \phi$	0.84805	0.82904	0.80386	0.77162	0.74896	0.84805	0.82904	0.80386
	$\frac{\sin \phi}{\phi}$	0.94900	0.94251	0.93389	0.92283	0.91500	0.94900	0.94251	0.93389
	$K^2 = \frac{1}{12} \times t_1^2$	21.33	14.3	11.41	8.84	6.60	13.02	7.68	5.60
11	$D = \left(1 + \frac{K^2}{r^2}\right) \times \phi \times (\phi + \frac{1}{2} \sin 2\,\phi) - 2 \sin 2\,\phi$	0.0028241	0.002537	0.0032086	0,0046441	0.0059800	0.0021218	0.002128	0.0028885
	$D_s = D + 2.88 \times \frac{K}{r^2} \times \phi \times (\phi - \frac{1}{2} \sin 2\,\phi)$	0.0033540	0.002851	0.0034592	0.0048539	0.0062016	0.0024322	0.002291	0.0030079
	$\frac{D}{D_s}$	0.8420	0.8900	0.92755	0.9568	0.9643	0.8724	0.9289	0.9603
	$\frac{2 \sin \phi}{D}$	375.28	440.8	370.77	273.93	221.61	499.50	525.60	411.85
	P	4813	4188	3563	2938	2313	3563	2938	2313
	$P_1 = P \times \frac{R_u}{r}$	5271	4460	3744	3055	2386	3823	3076	2394
	$P_1 \times r$	442,800	447,800	431,100	393,600	337,700	327,800	314,400	279,900
10	$p_1{}^r - P_o = \frac{2 \sin \phi}{D} \times p_1 \times \phi \times \frac{K^2}{r}$	280,500	166,100	87,600	46,400	17,800	161,900	72,100	30,100
	P_o	162,300	281,700	343,500	347,200	319,900	165,900	242,300	249,800
12	$M_o = \div (p_1{}^r - P_o) \times r - \left(\frac{\sin \phi}{\phi}\right)$	1,201,700	958,700	666,900	461,400	214,200	708,000	423,600	232,600
	$M_o^1 = M_o \times \frac{D}{D_s}$	1,011,800	853,200	618,600	441,500	206,600	617,700	393,500	223,400
4	$P_1 = p_1{}^r - (p_1{}^r - P_o) \cos \phi$	204,900	310,100	360,700	357,800	324,400	190,500	254,600	255,700
13	$M_1 = (p^r - P_o) \times r \left(\frac{\sin \phi}{\phi} - \cos \phi\right)$	2,378,600	1,892,000	1,311,600	904,000	418,400	1,398,700	836,100	457,500

	433,300	776,700	1,220,200	403,500	864,900	1,216,600	1,684,000	2,378,600	
$M'_1 = M_1 \times \frac{D}{D_o}$	+349 +73	+353 −3	+257 −71	+358 +140	+407 +61	+392 +16	+356 −58	+234 −94	Extr. Intr.
$S_o = \frac{P_o}{t_1 \times 144} \pm \frac{6\,M'_o}{t_1^2 \times 144}$									
$S_1 = \frac{P_1}{t_2 \times 144} \pm \frac{6 \times M'_1}{t_2^2 \times 144}$	+390 −16	+462 −126	+403 −199	+317 +71	+382 −14	+392 −58	+409 −139	+336 −178	Intr. Extr.
	Abutm.								Crown

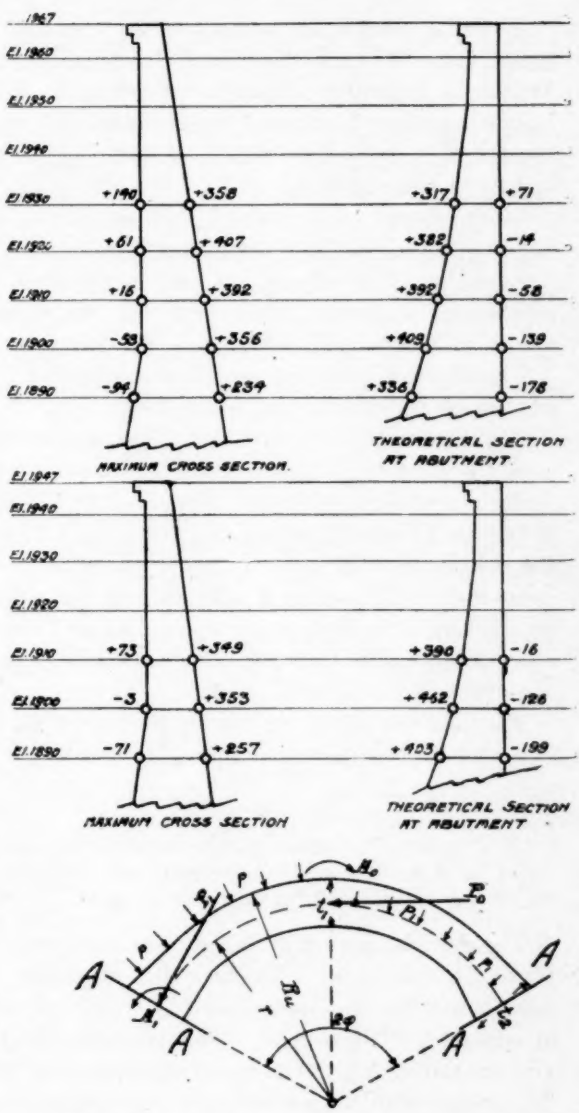


FIG. 9—DIAGRAM FOR CALCULATION OF CONCOW DAM

CONCOW CREEK DAM

In Fig. 8 details are shown on the Concow Creek dam, also called Lake Willenor dam, built for the Thermalito and Table Mountain Irrigation Districts, of which S. J. Norris was chief engineer and F. E. Baxter was resident engineer. The Dam is about 100 ft. high, with length of upstream radius at crest 180.6 ft. and at bottom 78 ft.

In the design of this dam, the method in Fig. 2 was used. When applying the Cain formulas p was taken as the full water pressure. The calculations are shown on Fig. 9 and the accompanying table. It is seen that the tension at the abutments is rather high, but since the method in Fig. 2, plane AA has been used in this particular case, this tension represents the imaginary tension inside the rock.

The dam is thicker at the abutments than further out on the arch to bring the stresses down to a conservative value. This additional thickness is made decreasing from a maximum amount at the rock junction to zero approximately 15 per cent out from the abutments. In this way the material is put where it does the most good. This dam is also an overflow dam, provided with flashboards 3 ft. high so as to keep water level to the maximum elevation possible after the rainy season has passed and to direct the overflow towards the middle.

The dam was let by contract to the lowest bidder, J. S. Greaves, Oroville, California, at the following prices:

905 cu. yd. of loose rock	@	$ 1.50
2,156 cu. yd. of solid rock	@	7.90
6,332 cu. yd. of 1:2½:5 concrete, including everything except cement	@	7.45
Per cu. yd. of reinforced 1:2:4 concrete, exclusive of cement and steel	@	19.50
Per ft. of grout pipe installed (exclusive of pipe)	@	.25

The dam is located 26 miles from the nearest railroad station (Oroville, California). Being a slim structure, a richer concrete mix than usual was used with 1¼ barrels of cement per cu. yd. of concrete. The weight of the concrete was 149 lb. per cu. ft. and the strength at 28 days averaged close to 1900 lb. per sq. in., fluctuating with the variation in the amount of cement used and the season in which the specimen was made, whether in the hot or in the cold. It was not possible to keep the cylinders (6 in. x 9 in. and 10 in. x 15 in.) under constant temperature in the

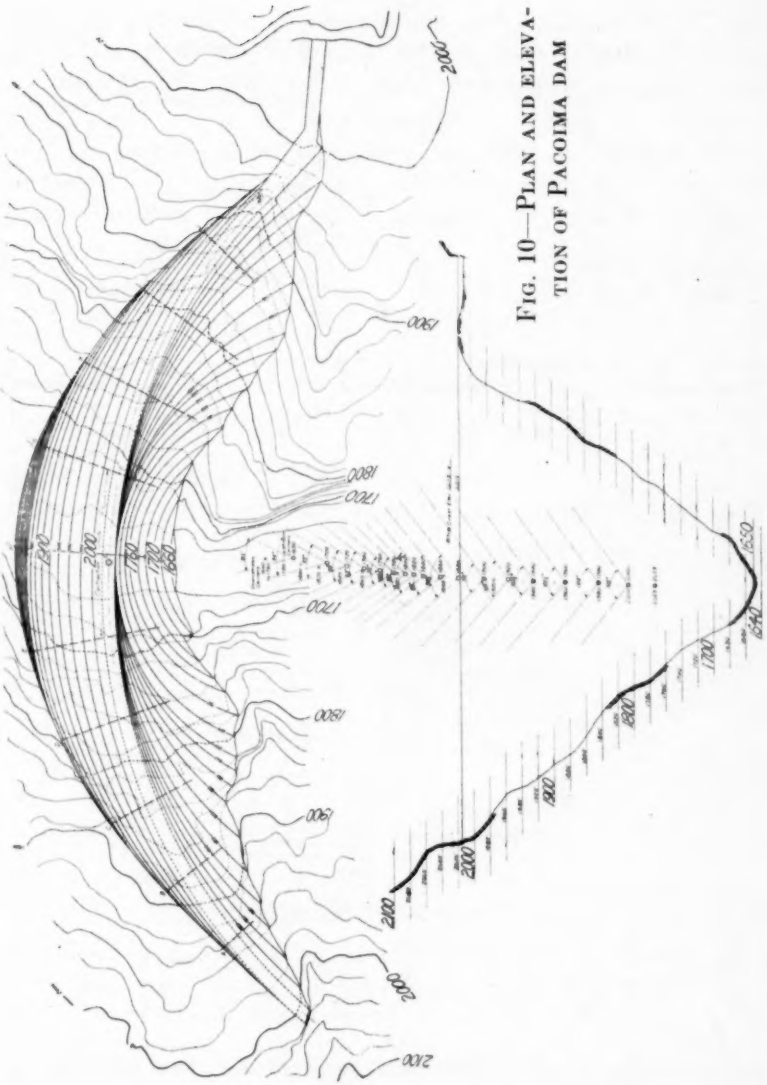


FIG. 10—PLAN AND ELEVATION OF PACOIMA DAM

field. The mixing plant was located at a sufficient elevation above the dam to allow chuting the concrete in place. Sand and gravel of good quality were found very close to the dam site.

PACOIMA DAM

In Figures 10, 10A and 10B, details are shown of the Pacoima Dam, built by the Los Angeles County Flood Control District of which J. W. Reagan was chief engineer until three years

FIG. 10B—PACOIMA DAM. TYPICAL PLAN OF CONTRACTION JOINT

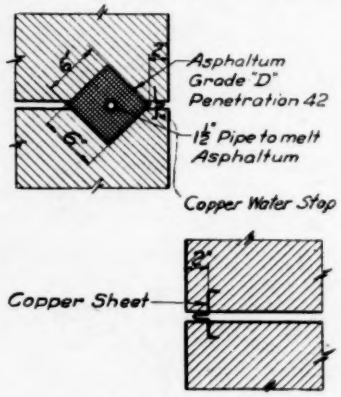


FIG. 10B—DETAIL OF SMITH'S ASPHALTUM WATER STOP, PACOIMA DAM

FIG. 10B—DETAIL OF COPPER SHEET WATER STOP

ago, when he became consulting engineer and E. Court Eaton became chief engineer. As the name implies, the purpose of the reservoir formed by the dam is to take care of flood waters due to torrential rains. The total storage in this reservoir amounts to 12,000 acre feet only, but it is intended to utilize this storage capacity several times per season by alternately emptying and

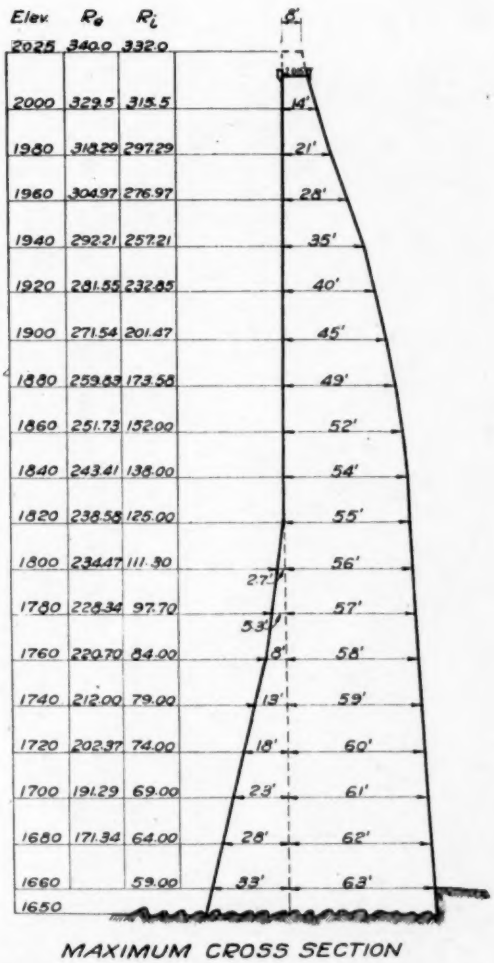


FIG. 10A—PACOIMA DAM. MAXIMUM CROSS SECTION

filling it as many times as the particular season may require. The water from the reservoir is to be let out at a rate slow enough to avoid damage to land below, and if possible to be all absorbed by the so-called gravel cone at the head of the valley, to help supply the irrigation pumping demand during the dry season.

The construction work was let to the lowest bidder, Bent

FIG. 10C—PACOIMA DAM. HEIGHT ABOVE FOUNDATION 373 FT.; CREST LENGTH 680 FT.; 225,000 CU. YDS. PLAIN CONCRETE

Brothers, Inc., Los Angeles, at the following unit prices on the most important items:

95,000 cu. yd. of mixed excavation	@	$ 4.00
2,000 cu. yd. of rock excavation, no blasting	@	6.00
225,000 cu. yd. of plain concrete, exclusive of cement	@	4.70
620 cu. yd. of reinforced concrete, exclusive of steel and cement	@	11.00
1,200 lin. ft. of 2 in. galvanized iron pipe railing to place	@	.40
1,900 lin. ft. of asphaltum water stop with steampipe—to place	@	.46
1,000 lin. ft., more or less, 3 in. diameter holes into bedrock, placing pipe and pressure grouting under 175 lb. per sq. in. pressure	@	4.00

The concrete material, gravel, was available within a mile of the damsite and the railroad (San Fernando station of the Southern Pacific) is only about four miles away. The crest length is 700 ft. On account of the great height of the dam, 373 ft. above the foundation and 365 ft. above streambed, and the importance of the location 20 miles above the City of Los Angeles, it was decided to use five sacks of cement per cubic yard of concrete, although the sand available is of an excellent quality and grading, testing at least 25 per cent higher than standard Ottawa sand.

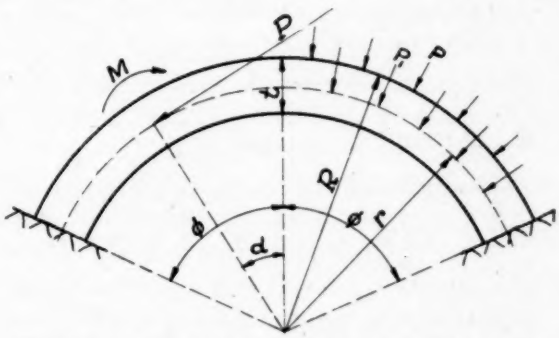


FIG. 11—DERIVATION OF CONSTANTS FOR DESIGN OF ARCH DAMS

TABLE TO ACCOMPANY FIG. 11

EQUATIONS 1 TO 7 INCLUSIVE ARE FROM CAIN'S ANALYSIS

	Number of Formula in Cain's Paper.
① $P = p_1 r - (p_1 r - P_o) \cos \alpha$	①
③ $M = (p_1 r - P_o) r \left(\frac{\sin \phi}{\phi} - \cos \alpha \right)$	③
⑤ Where $p_1 r = p R$	page 235
⑥ $p_1 r - P_o = 2 \sin \phi \frac{\phi}{D_1} \frac{k^2}{r} \rho_1$	⑥

⑤ $D_s = D + 2.88\frac{k^2}{r^2}\phi(\phi - \frac{1}{2}\sin 2\phi)$ page 269

⑥ $D = \left(1 + \frac{k^2}{r^2}\right)\phi(\phi + \frac{1}{2}\sin 2\phi) - 2\sin^2\phi$ ⑪

⑦ $k^2 = \frac{1}{12}t^2$ page 236

⑧ Let $A = \left(\frac{r}{t}\right)^2$ then $\left(\frac{k}{r}\right)^2 = \frac{1}{12A}$ ⑨

④ $p_1 r - P_o = 2\sin\phi \times \frac{\phi}{D_s} \times \frac{k^2}{r} \times p_1$ but $\frac{k^2}{r} = \frac{r}{12A}$ and from ②

⑩ We have $p_1 r - P_o = \frac{\sin\phi \times p.R \times \phi}{6AD_s}$

from ⑤ & ⑥ we have

$$D_s = \left[\left(1 + \frac{1}{12A}\right)\phi(\phi + \tfrac{1}{2}\sin 2\phi) - 2\sin^2\phi\right] + \left[\frac{2.88}{12A}\phi(\phi - \tfrac{1}{2}\sin 2\phi)\right]$$

$$\therefore 6AD_s = \phi\left[6A\left(\phi + \tfrac{1}{2}\sin 2\phi - \frac{2\sin^2\phi}{\phi}\right) + \tfrac{1}{2}(\phi + \tfrac{1}{2}\sin 2\phi) + 1.44(\phi - \tfrac{1}{2}\sin 2\phi)\right]$$

⑪ $6AD_s = \phi\left[A\left(6\phi + 3\sin 2\phi - 12\frac{\sin^2\phi}{\phi}\right) + 1.94\phi - .47\sin 2\phi\right]$

⑫ let $K_1 = 6\phi + 3\sin 2\phi - 12\frac{\sin^2\phi}{\phi}$

⑬ and $K_2 = 1.94\phi - .47\sin 2\phi$

then $6AD_s = \phi[AK_1 + K_2]$

$$\therefore ⑭\ p_1 r - P_o = pR - P_o = pR\frac{\phi\sin\phi}{\phi(AK_1 + K_2)}$$

from ① & ③ $P = pR - (pR - P_o)\cos\alpha = pR\frac{(AK_1 + K_2) - \sin\phi\cos\alpha}{AK_1 + K_2}$

$$\therefore ⑮\ P = pR\frac{AK_1 + K_3}{AK_1 + K_2}$$

⑯ Where $K_3 = 1.94\phi - 0.47\sin 2\phi - \sin\phi\cos\alpha$

from ③ $M = (pR - P_o) \times r \times \left(\frac{\sin\phi}{\phi} - \cos\alpha\right)$

$$= pR\frac{\phi\sin\phi}{\phi(AK_1 + K_2)} \times r \times \left(\frac{\sin\phi}{\phi} - \cos\alpha\right)$$

$$⑰ = pRr\frac{\frac{\sin^2\phi}{\phi} - \sin\phi\cos\alpha}{AK_1 + K_2} = pRr\frac{K_4}{AK_1 + K_2}$$

⑱ Where $K_4 = \frac{\sin^2\phi}{\phi} - \sin\phi\cos\alpha$

let $C_1 = \frac{K_3}{K_1}$, $C_2 = \frac{K_4}{K_1}$, $C_3 = \frac{K_2}{K_1}$

⑲ then $P = p \times R \times \frac{A + C_1}{A + C_3}$

⑳ and $M = p \times R \times r \times \frac{C_2}{A + C_3}$

The values of C_1, C_2 & C_3 are as follows:

$$C_1 = \frac{K_3}{K_1} = \frac{1.94\phi - 0.47\sin 2\phi - \sin\phi\cos\alpha}{6\phi + 3\sin 2\phi - \frac{12\sin^2\phi}{\phi}}$$

$$C_2 = \frac{K_4}{K_1} = \frac{\frac{\sin^2\phi}{\phi} - \sin\phi\cos\alpha}{6\phi\ \tfrac{1}{2}\ 3\sin 2\phi - \frac{12\sin^2\phi}{\phi}}$$

$$C_3 = \frac{K_2}{K_1} = \frac{1.94\phi - 0.47\sin 2\phi}{6\phi + 3\sin 2\phi - \frac{12\sin^2\phi}{\phi}}$$

Reference—Paper No. 1483 Trans. A. S. C. E. 1922. "The Circular Arch under normal Loads" by Prof. Wm. Cain.

It is seen from Fig. 11A that the stresses have been kept moderate. It will also be noted from Fig. 11A and the accompanying table that a short cut method compared with Fig. 9 has been used in the calculations. This was devised by A. C. Hoff. The derivation of the constants in Fig. 11A is shown on Fig. 11. The stress sheet (Fig. 11) was calculated with the intention of constructing the dam to elevation 2025, but construction was temporarily stopped at elevation 2015. In the lower zone where apparent tension exists, in case the full water-load is figured as borne by the arch, this same full water load can also be borne by the shear action along the rock contact, creating only moderate shear stresses. The load therefore, divides between the two actions and actual tension in the faces can not exist to any extent. The action of Poisson's ratio also tends to eliminate tension in the faces towards lower levels.

The fact that concrete expands when wet is a well known phenomena. Professors Campbell and White at the University of Michigan, who have carried out a series of careful experiments extending over several years, give the expansion of concrete as between 0.02 and 0.04 per cent of its length when dry.

For concrete having a modulus of elasticity of 2,000,000 and a coefficient of expansion due to being wetted of 0.0002, such expansion would equalize a stretch due to a tension of 400 lb. per sq. in.

Along the upstream face where the heaviest tension (apparent or real) exists, the concrete is water-soaked and will, therefore, have its complete expansion with reservoir full.

Along the down stream face the concrete is less water soaked and it will not have expanded as much as 0.02 per cent, but the effect of this expansion in neutralizing the tension is not so much needed along the downstream face as along the upstream face.

The maximum foundation pressure exists at the bottom, being about 430 lb. per sq. in. along the inclined downstream face, in the middle. With Poisson's ratio between 1/5 and 1/6 the resulting axial or horizontal compression will be about 75 lb. per sq. in., at elevation 1650 on the downstream side at least in the middle, thus being able to compensate for a considerable arch tension at the downstream face. At elevation 1800 where the arch

TABLE TO ACC

2000	1980	1960	1940	1920	1900	1880	1860
329[5]	318[29]	304[97]	292[21]	281[55]	271[54]	259[83]	251[73]
14	21	28	35	40	45	49	52
1,563	2,813	4,063	5,313	6,563	7,813	9,063	10,303
105	104	102½	103½	103	101	94½	88
322.5	307.79	290.97	274.71	261.55	249.04	235.33	225.73
530.64	214.82	107.99	61.61	42.76	30.63	23.07	18.84
515,009	895,350	1,239,033	1,552,512	1,847,813	2,121,542	2,354,839	2,596,091
166.090	275.580	360.539	426.491	483.295	528.349	554.164	586.016
3.4707	3.5437	3.6531	3.5802	3.6166	3.7625	4.3069	4.9798
−0.69671	−0.71208	−0.73513	−0.71976	−0.72744	−0.75817	−0.87302	−1.01579
8.6631	8.9408	9.3817	9.0860	9.2312	9.8316	12.2665	15.5909
534.1107	218.3637	111.6431	65.1902	46.3766	34.3925	27.3769	23.8198
539.3031	223.7608	117.3717	70.6960	51,9912	40,4616	35.3365	34.4309
.99037	.97588	.95119	.92212	.89201	.85000	.77475	.69181
510,049	873,754	1,178,613	1,431,602	1,648,268	1,803,311	1,824.412	1,796,002
−214,567	−876.985	−2,258,151	−4,342,129	−6,762,070	−9,900,211	−13,691,120	−17,288,807
5.5021	5.6211	5.7997	5.6806	5.7401	5.9782	6.8675	7.9731
1.33477	1.36544	1.41146	1.38078	1.39612	1.45747	1.68659	1.97148
8.6631	8.9408	9.3817	9.0860	9.2312	9.8316	12.2665	15.5909
536.1421	220.4411	113.7897	67.2906	48.5001	36.6082	29.9375	25.8131
539.3031	223.7608	117.3717	70.6960	51.9912	40.4616	35.3365	34.4309
.99414	.98516	.96948	.95183	.93285	.90476	.84721	.77875
511,991	882.033	1,201,276	1,477,127	1,723,732	1,919,486	1,995,043	2,021,706
411,071	1,681,653	4,335,682	8,329,895	12,977,923	18,784,547	26,449,916	33,554,709
+299	+372	+412	+432	+462	+482	+497	+506
+207	+206	+172	+136	+110	+74	+21	−26
0	0	0	0	1	0	0	0
0	0	0	0	3	9[6]	14	19
14	21	28	35	44	54[5]	63	71
+341	+451	+528	+576	+551	+509	+498	+475
+167	+133	+68	+10	−7	−19	−58	−79
0	0	0	0	1	0	0	0
0	0	0	0	3	12	17	24
14	21	28	35	44	57	66	76
+341	+451	+528	+576	+551	+475	+463	+427
+167	+133	+68	+10	−7	−7	−43	−57

tension is the greatest (on the downstream side 63), it is found that the action of Poisson's ratio, due to the weight of the dam above just about compensates for this tension. The action of Poisson's ratio is as positive as the action of the elasticity of the material and can be taken into full consideration when looking for means of relieving the tension. The lateral expansion begins as soon as the vertical compression begins. It is not like the action of the time factor, dependent upon a certain high value of

OMPANY FIG. 11A

1840	1820	1800	1780	1760	Elevation	
243[41]	238[18]	234[47]	228[34]	220[71]	R	
54	55	58[7]	62[3]	66	t_o	
11,563	12,813	14,063	15,313	16,563	p	
87	83	76½	70	63	2ϕ	
216.41	211.08	205.12	197.19	187.70	$r = R - \frac{1}{2} t_o$	
16.06	14.73	12.21	10.02	8.09	$A = \left(\frac{r}{t_o}\right)^2$	
2,814,550	3,056.926	3,297,352	3,496,570	3,655,454	$p \times R$ lbs. ft.	
609.097	645.256	676.353	689.489	686.129	$p \times R \times r \times 10^6$	
5.0996	5.6225	6.6198	7.9189	9.7968	C_1	Crown m = o
−1.04061	−1.14965	−1.35929	−1,63217	−2.02737	C_2	
16.1834	19.0205	25.1966	34.6587	50.3341	C_3	
21.1596	20.3525	18.8298	17.9380	17.8868	$A + C_1$	
32.2434	33.7505	37.4066	44.6787	58.4241	$A + C_3$	
.65625	.60302	.50338	.40151	.30615	$K = \frac{A + C_1}{A + C_3}$	
1,847,048	1,843,388	1,659,821	1,403,908	1,119,117	$P_o = K \times p \times R$ lbs.	
−19.657,742	−21,979,484	−24,577,477	−25,187,914	−23,809,307	$M_o = \frac{C_2}{A + C_3} \times p \times R \times$	
8.1652	9.0113	10.6375	12.7548	15.8176	C_1	Abutment m = ∞
2.02096	2.23903	2.65838	3.20373	3.99335	C_2	
16.1834	19.0205	25.1966	34.6587	50.3341	C_3	
24.2252	23.7413	22.8475	22.7748	23.9076	$A + C_1$	
32.2434	33.7505	37.4066	44.6787	58.4241	$A + C_3$	
.75132	.70344	.61082	.50975	.40921	$K = \frac{A + C_1}{A + C_3}$	
2,114,628	2,150,364	2,014,089	1,782,377	1,495,848	$P_1 = K \times p \times R$	
38,177,136	42,803,700	48,066,472	49,440,484	46,897,654	$M_1 = \frac{C_2}{A + C_3} \times p \times R \times$	
+519	+536	+493	+426	+346	Extrados	Crown Stresses
−43	−70	−101	−114	−110	Intrados	
0	0	0	0	0	Upstream Addition	Abutment Stresses
26	30	33	38	35	Downstream Addition	
80	85	91[7]	100[5]	101	t_1	
+433	+423	+391	+328	+295	Intrados	
−65	−71	−85	−82	−89	Extrados	
0	0	0	0	0	Upstream Addition	Abutment Stresses
27[5]	30	30	27	26	Downstream Addition	
81[5]	85	88[7]	89[3]	92	t_2	
+419	+423	+413	+397	+344	Intrados	
−59	−71	−97	−119	−118	Extrados	

unit stress being first reached in the material.

Due to the narrowness of the canyon, shear action predominates toward the bottom and pure arch action exists only towards the top. In the lower zone shear and arch action will divide the load between them and inasmuch as each action is sufficient to carry the whole load, the dam should be very safe for this portion. The shear cannot be transmitted from the middle to the abutments through the thick arch (horizontal

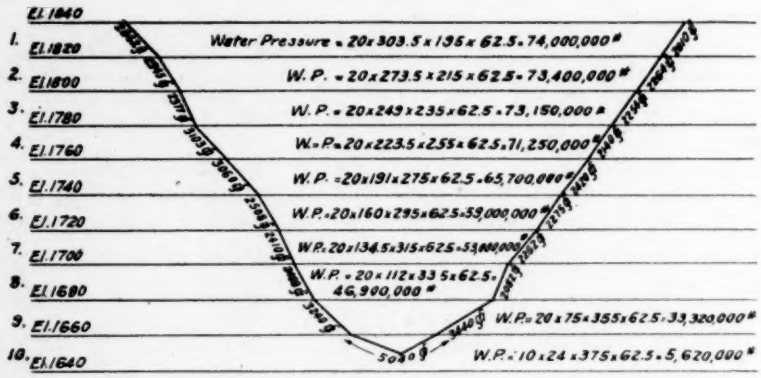


FIG. 11A—CALCULATION OF FINAL DESIGN, PACOIMA DAM

1. If all of the load *below El.* 1840 is assumed taken up by *Shear Action* the *Average Shear* in the martial along the area of rock contact will be

$$S = \frac{481,340,000 + 74,000,000}{144 \times (45708 + 2862 + 2010)} = \frac{555,340,000}{144 \times 50,580} = \underline{76.2 \text{ lbs./in.}^2}$$

2. Under the same assumption as for 1. the average shear below El. 1820 will be

$$S = \frac{407,940,000 + 73,400,000}{144 \times (41099 + 2345 + 2264)} = \frac{481,340,000}{144 \times 45,708} = \underline{73.1 \text{ lbs./in.}^2}$$

3. Under the same assumption as for 1. the average shear below El. 1800 will be

$$S = \frac{334,790,000 + 73,150,000}{144 \times (36468 + 2377 + 2254)} = \frac{407,940,000}{144 \times 41,099} = \underline{68.9 \text{ lbs./in.}^2}$$

4. Under the same assumption as for 1. the average shear below El. 1780 will be

$$S = \frac{26,3540,000 + 71,250,000}{144 \times (3103 + 31225 + 2140)} = \frac{334,790,000}{144 \times 36,468} = \underline{63.7 \text{ lbs./in.}^2}$$

5. Under the same assumption as for 1. the average shear below El. 1760 will be

$$S = \frac{197,840,000 + 65,700,000}{144 \times (3060 + 25745 + 2420)} = \frac{263,540,000}{144 \times 31,225} = \underline{58.6 \text{ lbs./in.}^2}$$

6. Under the same assumption as for 1. the average shear below El. 1740 will be

$$S = \frac{138,840,000 + 59,000,000}{144 \times (2508 + 20962 + 2275)} = \frac{197,840,000}{144 \times 25,745} = \underline{53.6 \text{ lbs./in.}^2}$$

7. Under the same assumption as for 1. the average shear below El. 1720 will be

$$S = \frac{85,840,000 + 53,000,000}{144 \times (2410 + 16290 + 2262)} = \frac{138,840,000}{144 \times 20,962} = \underline{45.9 \text{ lbs./in.}^2}$$

8. Under the same assumption as for 1. the average shear below El. 1700 will be

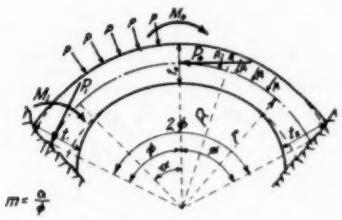
$$S = \frac{38,940,000 + 46,900,000}{144 \times (2488 + 11720 + 2082)} = \frac{85,840,000}{144 \times 16,290} = \underline{36.6 \text{ lbs./in.}^2}$$

9. Under the same assumption as for 1. the average shear below El. 1680 will be

$$S = \frac{33,320,000 + 5,620,000}{144 \times (5040 + 3240 + 3440)} = \frac{38,940,000}{144 \times 11,720} = \underline{23.1 \text{ lbs./in.}^2}$$

10. Under the same assumptions as for 1. the average shear below El. 1660 will be

$$S = \frac{5,620,000}{144 \times 5,040} = \underline{7.7 \text{ lbs./in.}^2}$$



NOMENCLATURE.

The values of C_1, C_2 & C_3 are

$$C_1 = \frac{1.94\phi - 0.47 \sin 2\phi - \sin\phi \cos\alpha}{6\phi + 3\sin 2\phi - \frac{12\sin^2\phi}{\phi}}$$

$$C_2 = \frac{\frac{\sin^2\phi}{\phi} - \sin\phi \cos\alpha}{6\phi + 3\sin 2\phi - \frac{12\sin^2\phi}{\phi}}$$

$$C_3 = \frac{1.94\phi - 0.47\sin 2\phi}{6\phi + 3\sin 2\phi - \frac{12\sin^2\phi}{\phi}}$$

NOTE—

The calculations are made on the assumption of an arch with fixed ends carrying the total water load with no help from cantilever.

Under the assumptions governing shear calculations we have the approximate increase in shear from the base upwards rather than the exact stress at any single point. In narrow canyons, the halves of the arch partially become horizontal cantilevers through whose vertical sections the load is transmitted by shear to the abutments. This transmission of the stress occurs only with deformation of the cantilever, which deformation is the result of the joint action of arch and horizontal cantilevers.

Reference—"The Circular Arch Under Normal Loads," by Prof. Wm. Cain, Paper No. 1483, Trans. A. S. C. E. 1922.

FIG. 11A

cantilever) without deformation, but the two actions, arch and punching shear, go together and the actual deformation is the result of the joint action. How the load actually divides between the various possible actions towards the bottom is a problem not yet solved by any one, but the principal action presumably is punching shear in connection with some sort of cantilever action both vertical and horizontal. The ultimate crushing strength of the concrete was well above 4000 lb. per sq. in. and the factor of safety should, therefore, be at least five.

The contraction joints, some details of which are shown, were closed somewhat too early. Observation on finished structures has shown that these joints do not open fully for quite a long time after construction is finished. They may show openings on

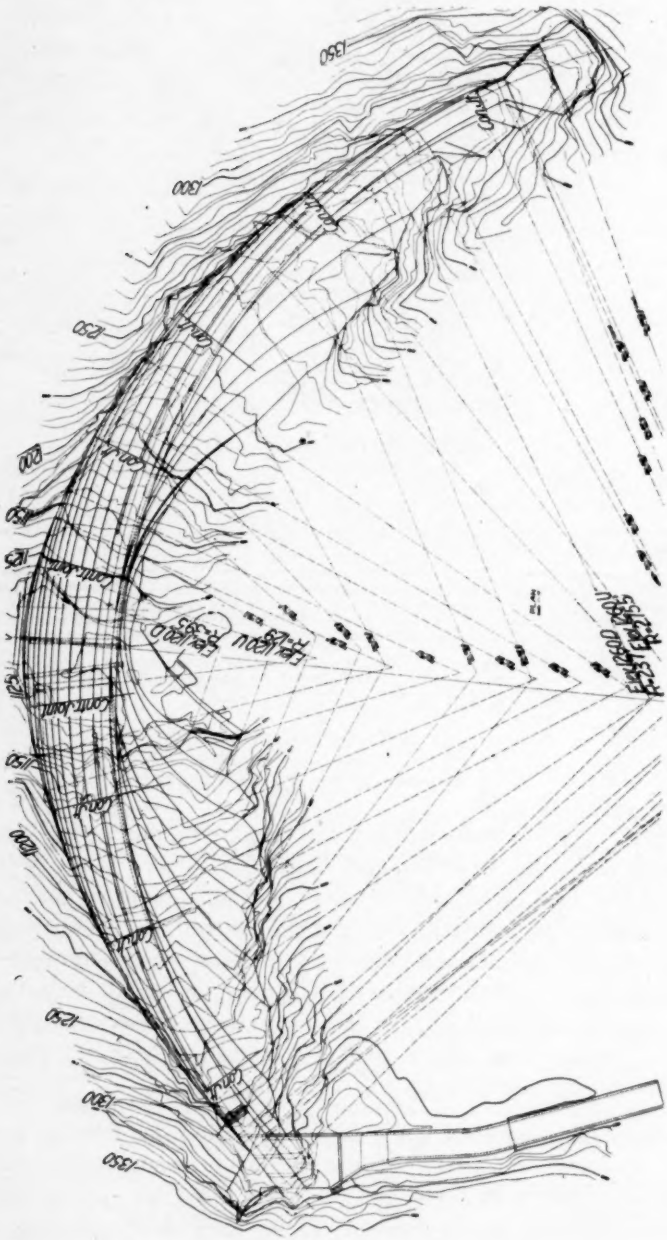


FIG. 12—PLAN—BIG SANTA ANITA DAM

the up and down-stream faces, but farther inside the body where the temperature is highest, due to the presence of the chemical heat and the fact that the structure has not been subject to compressive stresses, the voussoirs still have contact with one another.

If the joints had been grouted during the coldest season after the dam had withstood full water pressure once, the condition of the dam when loaded should correspond to that assumed when making the calculations shown in Fig. 11A. Any increase in temperature will relieve the bending stresses as the arch deflection becomes less with increase in temperature. The condition may actually arise where the expansion of the arch due to increase in temperature is equal to the contraction due to the arch compression in which case there are no bending moments to take care of.

As will be seen from the details, the contraction joints are provided with grout pipes, also with Smith asphaltum waterstops along the upstream face with a copper or galvanized iron stop (grout stop) along the faces. It is between these two stops that the grout is injected. The top of the contraction joint is generally not corked. The grout is injected to just fill the joint to the top. It is not desirable to have the crest of the dam grouted to the extent of exerting a pressure in an upstream direction with a cold dam body inasmuch as the load near the crest is always small compared with the cross section available to support it. At lower elevations there will be grout pressure due to the corresponding static head of the grout.

BIG SANTA ANITA DAM

Figures 12 and 12A show the plan and cross section of the Big Santa Anita dam also built by the Los Angeles County Flood Control District and finished a year ago. Figures 13 and 13A and accompanying table show the calculations. While the tension in the faces is apparently above 100 lb. per sq. in. at elevation 1160, this tension is not paired with a very high compression and this arch slice (and all others below) is located so close to the bottom that it obtains considerable support from punching shear.

Compared with the stresses in the Lake Spaulding Dam, the Santa Anita stresses are not high. Lake Spaulding dam as

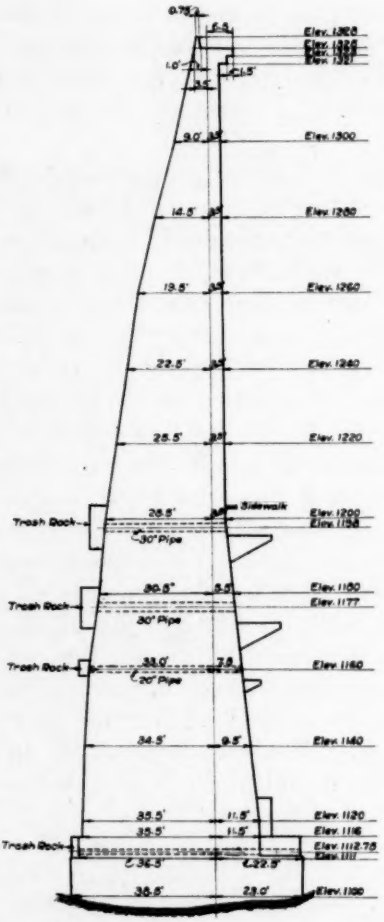


FIG. 12A—MAXIMUM SECTION BIG SANTA ANITA DAM

described in the Transaction of the American Society of Civil Engineers—Volume 78—1915—page 716 was designed at a time, when the simple arch formula was used practically exclusively.

Take for instance—at elevation 4725 the average stress found from the simple arch formula is 308 lb. per sq. in compression. Using the Cain formula, the abutment stresses are found to be

723 lb. compression and 289 lb. tension per sq. in. No particular indication of harm due to this high apparent tension is visible. Very likely the watersoaking effect of the concrete more than compensates for the expansion due to the tension.

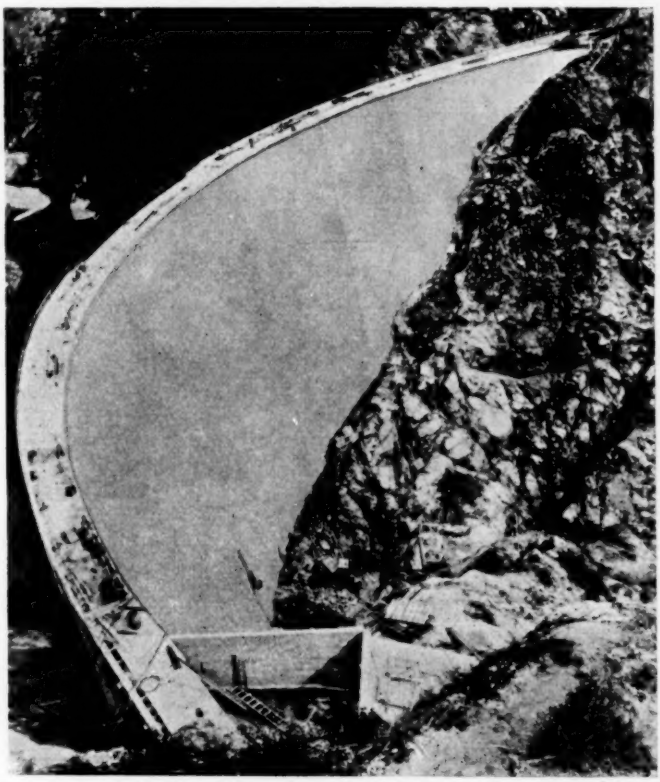


FIG. 12B—BIG SANTA ANITA DAM. HEIGHT 225 FT.; SPAN 515 FT.; THICKNESS AT CREST, 7 FT.; AT BOTTOM, 48 FT.

The Big Santa Anita dam is 225 ft. high above stream bed. The length of the upstream radius at the crest is 306 ft. and at the bottom it is 129 ft. long. The span is 515 ft. About 76,000 cu. yd. of concrete went into the dam.

The Pacoima Dam and this dam are thickened gradually from the middle towards the abutments except near the crest. Most

TABLE TO ACCOMPANY FIG. 13

	Elevation	1300	1280	1260	1240	1220	1200	1180	1160
	R_u ft.	296.5	287.0	275.5	267.0	256.0	238.0	220.0	190.0
	T ft.	12.5	18.0	24.8	31.6	34.0	37.3	39.8	42.9
	P lbs./ft.	1563	2813	4063	5313	6563	7813	9063	10313
	2θ	117.0°	112.5°	107°	109°	108°	92°	85°	66°
	θ	58.5°	56.25°	53.5°	54.5°	54.0°	46.0°	42.5°	33.0°
	r ft.	290.5	278.0	256.0	221.0	202.0	168.0	145.0	138.0
	$A = \left(\frac{r}{T}\right)^2$	540.0976	238.5295	103.5557	48.9114	35.2976	20.2862	13.2730	10.3477
	$p \times R_u$ lbs.	463,430	807,331	1,119,357	1,418,571	1,680,128	1,859,494	1,993,860	1,959,470
	$p \times R_u \times r$ lbs./ft.	134,626,400	224,438,000	286,555,400	313,385,900	339,385,900	312,395,000	289,109,700	270,406,900
Crown (m = 0)	C_1	2.7880	3.0215	3.3459	3.2212	3.2836	4.5475	5.3393	8.9431
	C_2	−0.55269	−0.60194	−0.67039	−0.64406	−0.65722	−0.92476	−1.09025	−1.84756
	C_3	6.1277	6.9463	8.1597	7.6832	7.9146	13.4051	17.5397	42.5473
	$A + C_1$	542.8856	241.5510	109.9016	52.1326	38.5812	24.8337	18.6123	19.2908
	$A + C_2$	546.2253	245.4758	114.7154	56.5946	43.2122	33.6913	30.8127	52.8950
	$K = \frac{A + C_1}{A + C_2}$	0.99388	0.98401	0.95804	0.92116	0.89283	0.73710	0.60405	0.36470
	$P = K \times p \times R_u$	460,594	794,422	1,072,389	1,306,731	1,500,069	1,370,633	1,204,391	714,619
	$M = \frac{C_2}{A + C_2} p \times R_u \times r$	−136,220	−550,352	−1,674,613	−3,567,752	−5,161,764	−8,574,629	−10,229,609	−9,444,995
North Abutment	α_1	55.0°	51.75°	51.5°	46.0°	45.5°	39.5°	30.5°	21.5°
	$m = \frac{\alpha_1}{\theta}$	0.94	0.92	0.96	0.845	0.845	0.86	0.715	0.65
	C_1	4.2171	4.5201	5.1564	4.5890	4.6796	6.5906	7.0302	11.2096
	C_2	0.87642	0.89670	1.14013	0.72377	0.73880	1.11234	0.60065	0.51206
	$A + C_1$	544.3147	243 0496	111.7154	53.5004	39.9772	26.8768	20.3032	21.5573
	$K = \frac{A + C_1}{A + C_2}$	0.99650	0.99012	0.97382	0.94533	0.92514	0.79774	0.65892	0.40755
	$P = K \times p \times R_u$	461,808	799,355	1,090,052	1,341,018	1,554,354	1,483,393	1,313,794	798,582
	$M = \frac{C_2}{A + C_2} p \times R_u \times r$	216,008	819,851	2,848,008	4,009,304	5,802,489	10,313,922	5,635,785	2,617,725

TABLE TO ACCOMPANY FIG. 13 (CONTINUED)

	Elevation	1300	1280	1260	1240	1220	1200	1180	1160
South Abutment	α_2	55.5°	49.25°	45.5°	45.5°	33.0°	32.0°	37.0°	28.0°
	$m = \frac{\alpha_2}{\theta}$	0.95	0.875	0.85	0.835	0.61	0.695	0.87	0.85
	C_1	4.2448	4.3861	4.7857	4.5589	4.0272	5.8863	7.7983	12.9344
	C_2	0.90414	0.76274	0.76948	0.69373	0.09144	0.42552	1.36871	2.14372
	$A + C_1$	544.3424	242.9156	111.3414	53.4703	39.3248	26.1725	21.0713	23.2821
	$K = \frac{A + C_1}{A + C_3}$	0.99655	0.98957	0.97059	0.94480	0.91004	0.77683	0.68385	0.44016
	$P = K \times p \times R_u$	461,831	798,910	1,086,437	1,340,266	1,528,984	1,444,511	1,363,501	862,480
	$M = \frac{C_2}{A + C_3} p \times R_u \times r$	222,840	697,372	1,922,136	3,842,898	718,164	3,945,538	12,842,346	10,959,007
Crown	$f = t\frac{P}{\times 144} \pm \frac{6 \times M}{t^2 \times 144}$	+292 +220	+377 +235	+455 +191	+568 +126	+615 +103	+646 − 52	+561 − 97	+362Extr. −118Intr.
North Abutment	$f = \frac{P}{t_1 \times 144} \pm \frac{6 \times M}{t_1^2 \times 144}$	+314 +198	+413 +203	+466 +116	+321 +127	+329 +119	+362 + 38	+256 + 88	+147Intr. + 67Extr.
South Abutment	$f = \frac{P}{t_2 \times 144} \pm \frac{6 \times M}{t_2^2 \times 144}$	+315 +195	+398 +218	+326 +160	+295 +129	+284 +246	+313 +143	+529 + 79	+380Intr. −104Extr.

The values of the constants C_1, C_2 and C_3 are as follows:

$$C_1 = \frac{1.94 \times \theta - 0.47 \sin 2\theta - \sin\theta \times \cos\alpha}{6 \times \theta + 3 \times \sin 2\theta - 12 \times \frac{\sin^2\theta}{\theta}}$$

$$C_2 = \frac{\frac{\sin^2\theta}{\theta} - \sin\theta \times \cos\alpha}{6 \times \theta + 3 \sin 2\theta - 12 \times \frac{\sin^2\theta}{\theta}}$$

$$C_3 = \frac{1.94\,\theta - 0.47 \sin 2\theta}{6\,\theta + 3 \sin 2\theta - 12 \times \frac{\sin^2\theta}{\theta}}$$

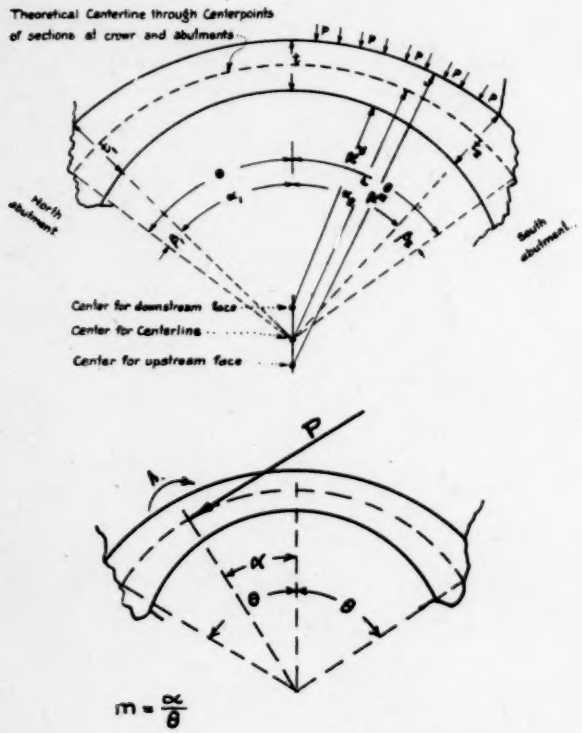


FIG. 13—DIAGRAMS FOR CALCULATIONS FOR BIG SANTA ANITA DAM

TABLE TO ACCOMPANY FIG. 13 (CONTINUED)

	Elev.	1300	1280	1260	1240	1220	1200	1180	1160
Scaled from Drawing	R_u	296.5′	287.0′	275.5′	267′	256′	238′	220′	190′
	R_d	284′	269′	237′	184.5′	160′	120′	107′	86′
	t	12.5′	18′	23′	26′	29′	32′	36′	40.5′
	r	290.5′	278′	256′	221′	202′	168′	145′	138′
	t_1	12.5′	18′	26′	41.5′	48′	51.5′	53′	52′
	t_2	12.5′	18′	31′	44′	40′	44′	42′	43.5′
	$2\,\Theta$	117°	112.5°	107°	109°	108°	92°	85°	66°
	α_1	55°	51.75°	51.5°	46°	45.5°	39.5°	30.5°	21.5°
	β_1	3.5°	4.5°	2.0°	8.5°	8.5°	6.5°	12°	11.5°
	α_2	55.5°	49.25°	45.5°	45.5°	33°	32°	37°	28°
	β_2	3°	7°	8°	9°	21°	14°	5.5°	5°
	T	12.5′	18′	24.8′	31.6′	34.0′	37.3′	39.8′	42.9′
	P	1,563	2,813	4,063	5,313	6,563	7,813	9,063	10,313

Average theoretical thickness $T = \dfrac{4\,t + t_1 + t_2}{6}$

other Constant Angle Arches have been thickened close to the abutments only.

The Ross Construction Co., Los Angeles, were the low bidders and obtained the contract at the following unit prices:

60,000 cu. yd. of excavation—mixed	@	$ 5.50
2,000 cu. yd. of rock excavation (no blasting)	@	8.75
70,000 cu. yd. of plain concrete	@	4.65
300 cu. yd. of reinforced concrete	@	15.00
4,000 lin. ft. placing 2 in. grout and drain pipes and fittings	@	.30
700 lin. ft. placing asphaltum filler with steam pipe	@	.50
100 lin. ft. placing steel discharge pipes	@	1.00
1,000 ft. 3 in. grout holes	@	2.00
28,000 cu. yd. excavation for roadway to damsite	@	1.12

Further details can be obtained from B. F. Jakobsen's paper,* also from articles in Western Construction News, Aug. 25, 1926, by J. W. Reagan and by E. Court Eaton in the Nov. 25, 1927, issue.

B. F. Jakobsen was engineer in charge of the Pacoima Dam and the Big Santa Anita Dam until three years ago. R. B. Metcalf was resident engineer on the Big Santa Anita Dam and Kenneth Harrison was resident engineer on the Pacoima Dam.

DIABLO CANYON DAM

A large constant angle arch dam now nearing completion is shown in Figures 14 and 14A, 14B and 14C. This is the Diablo Canyon dam owned by the City of Seattle, Washington. This represents typical construction of a high arch dam spanning a large gap. Two abutments of gravity section are run out to meet the arch in order to cut down the length of the upstream radius. The arch span proper is 540 ft. and the total gap closed has a maximum width of 950 ft. The maximum height above river bed is 363 ft. and the thickness at the bottom 116.5 ft. Length of upstream radius at the crest is 390 ft. and at the bottom 148.6 ft.

The gravity abutments are built to take care of the overflow during high water in the river and the spillway capacity thus obtained is in excess of 100,000 sec. ft. Normally the spillway bays are closed by means of radial gates. A pressure tunnel connects the reservoir with a powerhouse to be constructed about 2000 ft. below the dam.

*"Stresses in thick Arches of Dams," Trans. of Am. Soc. C. E., 1927, V. 90, p. 583.

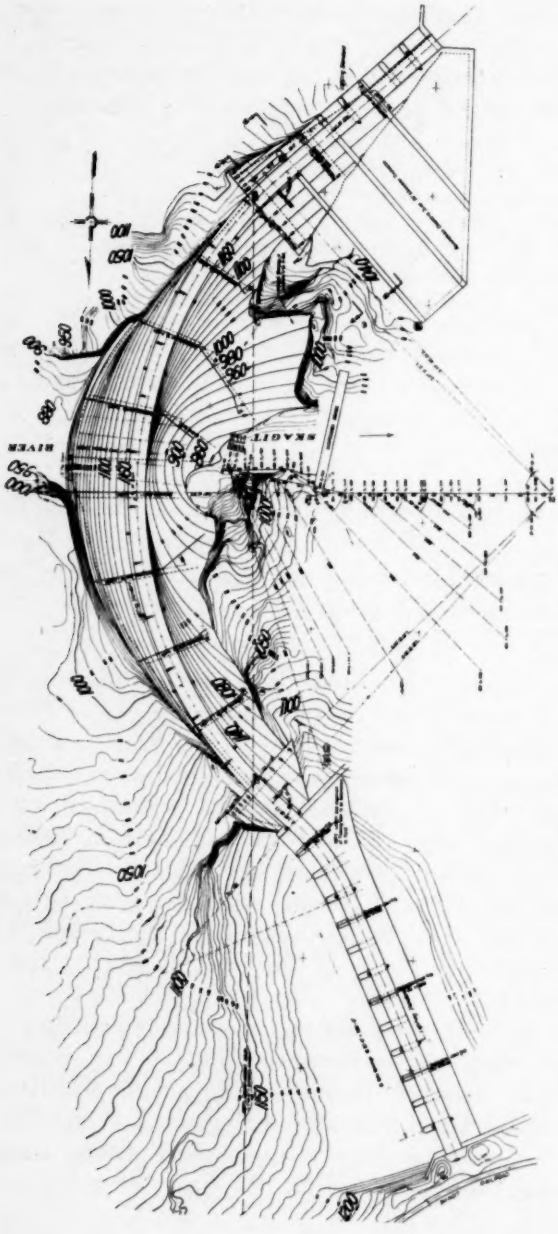


FIG. 14—PLAN OF DIABLO CANYON DAM

Referring to Fig. 14, it will be noted that the gravity abutment has a base thickness of 85 per cent of its height and also that the axis of the abutment is not tangent to the arch crest but inclined from the tangent by an angle of 5 degrees. The abutments are subjected to two sets of external forces: first, the normal water pressure on the upstream face, and second, the resultants of all the arch forces.

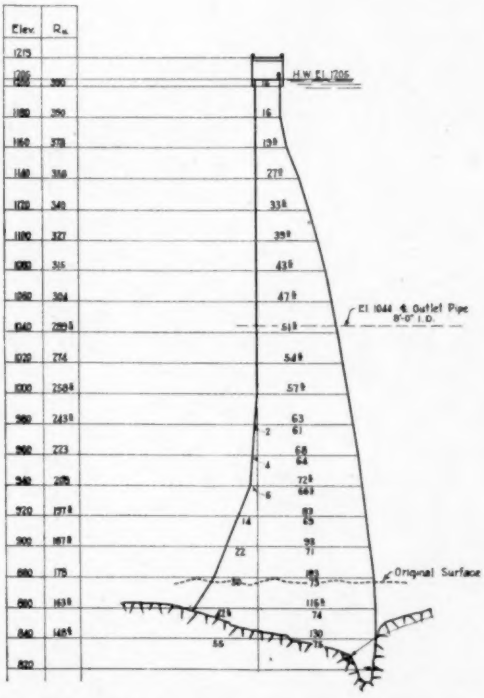


FIG. 14A—MAXIMUM SECTION, DIABLO DAM

The arch resultants may be in turn resolved into their two components, thrust and shear. The arch thrusts are themselves eccentric with respect to the neutral axis of the arch.

In designing the gravity abutments for the Diablo dam it was necessary to find the magnitude and direction of the resultant of all the arch thrusts and radial shears and place the axis of the abutment parallel to this resultant. As a further means of increasing the safety factor of the abutment against overturning,

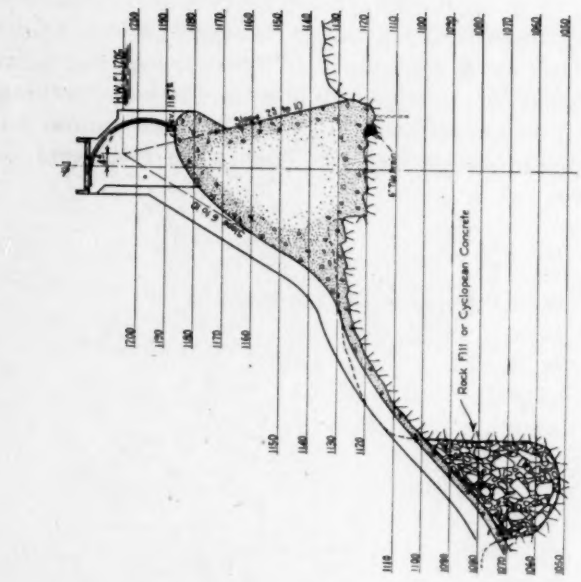


FIG. 14B—SECTIONS, DIABLO DAM

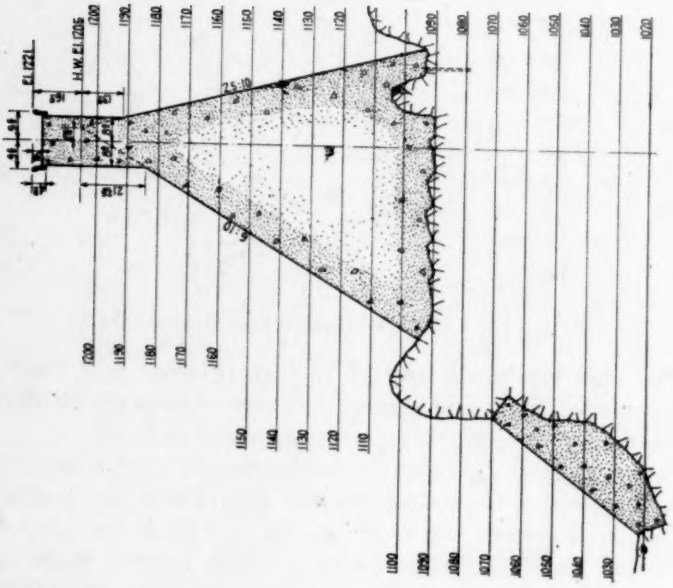
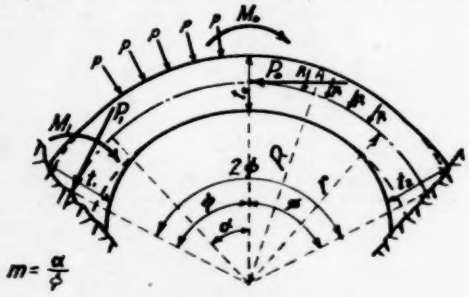


FIG. 14D—DIABLO DAM, 370 FT. HIGH ABOVE FOUNDATION. WIDTH OF GAP CLOSED, 950 FT.; LENGTH OF UPSTREAM RADIUS AT CREST, 390 FT., AT BOTTOM 148.6 FT. 316,000 CU. YDS. OF CONCRETE IN DAM PROPER

in order that it should be comparable to that of the arch itself, the base width of the abutment was made 85 per cent of its height.

As will be observed from Fig. 14, most of the contraction joints are not radial. On account of the fairly large thickness of the arch and the short radius used, this could not be done so well. The grout pipes used in this dam are of an improved type, patented by Arthur Troiel, San Francisco, California, consisting of sheet iron half cylinders and fittings inserted in each face of the contraction joints. When contraction takes place, they offer



NOMENCLATURE.

The values of C_1, C_2 & C_3 are

$$C_1 = \frac{1.94\phi - 0.47 \sin 2\phi - \sin\phi \cos\alpha}{6\phi + 3\sin 2\phi - \frac{12 \sin^2\phi}{\phi}}$$

$$C_2 = \frac{\frac{\sin^2\phi}{\phi} - \sin\phi \cos\alpha}{6\phi + 3\sin 2\phi - \frac{12\sin^2\phi}{\phi}}$$

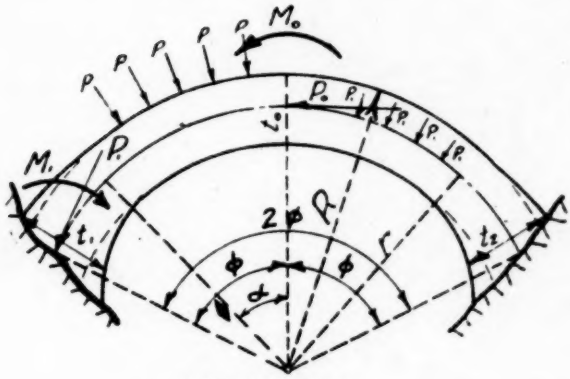
$$C_3 = \frac{1.94\phi - 0.47 \sin 2\phi}{6\phi + 3\sin 2\phi - \frac{12\sin^2\phi}{\phi}}$$

NOTE:

The calculations are made on the assumption of an arch with fixed ends carrying the total water load with no help from cantilever.

These calculations are based on actual lines of excavation as of Oct. 15, 1928.

FIG. 15—FINAL DESIGN, DIAGRAM FOR COMPUTATION DIABLO DAM



NOMENCLATURE

Computations of Stresses are made in accordance with Prof. Wm. Cain's Paper No. 1603, Trans. A. S. C. E. 1927, "Stresses in Thick Arches of Dams."

NOTE: These computations are made under the assumption that the arches shall take the *full water pressure* and that arches are fixed at the abutments.

FIG. 15A—FINAL DESIGN. DIAGRAM FOR COMPUTATIONS FOR DIABLO DAM

100 per cent exit opening for the grout as against perhaps 50 per cent in a slotted pipe and they are cheaper to install.

Figures 15 and 15A and accompanying table give the method and result of the stress calculation for the arch down to elevation 920. From and including elevation 960 to the bottom, that is the thick portion of the arch dam, a graphical solution (see also Fig. 15A) for obtaining the arch stresses has been used, as shown on Figures 16, 17, 18, 19 and 20. This method (drawings by G. Goodall) has the advantage that the location of the center line of pressure is visible and if its direction should be unfavorable at the abutments the downstream face of the dam can easily be changed here to improve general conditions at the abutments.

The arch is short and thick below elevation 900 and punching shear stresses are very low even assuming all the load taken up by punching shear. This dam is therefore, exceptionally safe below elevation 900, notwithstanding the fact that apparent arch stresses show up high in the calculations.

Fig. 21, shows the installation of the grout pipes and water-stops on the face of the contraction joint and Figures 22, 22A and 22B give some details of the bridge across the dam. The bridge was designed by Fred Vogt.

TABLE TO ACCOMPANY FIG. 15A

960	940	920	900	880	Elevation
223.0	208.0	197.5	187.5	178.0	R_e (Extrados)
155.0	135.5	114.5	94.5	75.0	R_i (Intrados)
68.0	72.5	83.0	93.0	103.0	$t_o = R_e - R_i$
189.0	171.75	156.0	141.0	126.5	$r = \frac{1}{2}(R_e + R_i)$
186.943	169.167	152.248	135.730	119.172	$r_n = \frac{t_o}{\log_e\left(\frac{R_e}{R_i}\right)}$
34948.807	28614.091	23188.894	18423.990	14202.442	$(r_n)^2$
102°	74°	67°	67°	67°	2ϕ
51°	37°	33.5°	33.5°	33.5°	$\phi°$
.8901183	.6457721	.5846855	.5846855	.5846855	$\phi = .0174533\ \phi°$
.9781575	.9612615	.9205053	.9205053	.9205053	$\sin 2\phi$
.2079117	.2756374	.3907311	.3907311	.3907311	$\cos 2\phi$
.7771459	.6018151	.5519370	.5519370	.5519370	$\sin \phi$
.6293204	.7986354	.8338858	.8338858	.8338858	$\cos \phi$
.1269185	.0680690	.0560105	.0560105	.0560105	$1 - \frac{\sin \phi}{\phi}$
1.3791170	1.1264028	1.0449381	1.0449381	1.0449381	$\phi + \frac{1}{2}\sin 2\phi$
.4010395	.1651413	.1244328	.1244328	.1244328	$\phi - \frac{1}{2}\sin 2\phi$
1.3570238	1.1217000	1.0420455	1.0420455	1.0420455	$1 - \frac{\cos 2\phi}{\phi}$
1.0110033	1.0152689	1.0246440	1.0388271	1.0614909	$\frac{r}{r_n}$
.0110260	.0153060	.0247669	.0391231	.0622487	$\left(\frac{K}{r_n}\right)^2 = \frac{1}{12}\left(\frac{t_o}{r_n}\right)^2$
.0502553	.0293343	.0378668	.0583386	.0916182	$D_n = (\phi + \frac{1}{2}\sin 2\phi)\left(1 + \frac{K^2}{{r_n}^2}\right) - \frac{1 - \cos 2\phi}{\phi} + 2.88\ \frac{r}{r_n}\left(\frac{K^2}{r_n}\right)(\phi - \frac{1}{2}\sin 2\phi)$
30.927918	41.03149	29.15149	18.92184	12.04863	$\frac{2 \sin \phi}{D_n}$
15,313	16,563	17,813	19,063	20,313	p
3,414,799	3,445,104	3,518,068	3,574,312	3,615,714	$p \times R_e$

TABLE TO ACCOMPANY FIG. 15A (CONTINUED)

1,164,485	2,163,622	2,540,017	2,645.995	2,711,827		$p\,R_s - P_o = p\,R_r \frac{2\sin\phi}{D_n}\left(\frac{K}{r_n}\right)^2$
2,250,314	1,281,482	978,051	928,317	903,887		$P_o = p\,R_c - p\,R_s\left[\frac{2\sin\phi}{D_n}\left(\frac{K}{r_n}\right)^2\right]$
−27,629,182	−24,914,170	−21,659,961	−20,115,662	−18,101,128		$M_o = -(p\,R_s - P_o)\,r_n\left(1 - \frac{\sin\phi}{\varphi}\right)$
2,681,965	1,717,159	1,399,984	1,367,854	1,354,360		$P_1 = p \times R_c - (p\,R_c - P_o)\cos\phi$
53,064.919	48,787,980	42,578,478	39,542,741	35,582,638		$M_1 = M_o + (p\,R_c - P_o)\,r_n\,(1 - \cos\phi)$
2.057	2.583	3.752	5.270	7.328	Crown	$C = r - r_n$
26,203	31,756	47,649	67,030	91,060		$I = {}^1/_{12}\,t_o^3$
+414	+272	+173	+128	+95		Extrados: $S = \frac{P_o}{t_o \times 144} - \frac{M_o + P_o C}{I \times 144} \times \frac{r_n}{R_e}\left(\frac{t_o}{2} + C\right)$
−5	−76	−50	−24	−0.5		Intrados: $S = \frac{P_o}{t_o \times 144} + \frac{M_o + P_o C}{I \times 144} \times \frac{r_n}{R_i}\left(\frac{t_o}{2} - C\right)$
10	2.5	2	0	0	North Abutment	Upstream Add = a =
24	12	4	3	1		Downstream add = b =
102	87	89	96	104		t_1 =
88,434	54,875	58,747	73,728	93,739		$I_1 = {}^1/_{12} \times t_1^3$
+393	+462	+408	+366	+329		Intrados: $S_i = \frac{P_1}{t_1 \times 144} + \frac{M_1 + P_1\left(C + \frac{a-b}{2}\right)}{I_1 \times 144} \frac{r_n}{R_i}\left(\frac{t_o}{2} - C + b\right)$
−18	−55	−91	−59	−40		Extrados: $S_e = \frac{P_1}{t_1 \times 144} - \frac{M_1 + P_1\left(C + \frac{a-b}{2}\right)}{I_1 \times 144} \frac{r_n}{R_e}\left(\frac{t_o}{2} + C + a\right)$
13	5	0	0	2	South Abutment	Upstream Add = a =
25	28.5	29	24	18		Downstream Add = b =
106	106	112	117	123		t_2 =
99,251	99,251	117,077	133,468	155,072		$I_2 = {}^1/_{12} \times t_2^3$
+380	+292	+231	+229	+ 230		Intrados: S_i
−14	+30	+30	+22	+13		Extrados: S_e

The reservoir will store 90,000 acre ft. of water and will regulate the Skagit River to a certain extent for the benefit of an existing power-plant located approximately eight miles below.

In the near future a large power plant will be finished below the Diablo Dam utilizing about 335 ft. head.

This dam is being constructed by Winston Bros., Minneapolis, who were low bidders at the following unit prices. Cement furnished by the City of Seattle at $2.50 per bbl. is included in the bid:

River diversion and control—lump sum	@	$190,000.00
63,000 cu. yd. solid rock excavation above elv. 900	@	3.50
3,000 cu. yd. solid rock excavation below elv. 900	@	6.75
7,000 cu. yd. solid rock excavation in tunnel and shaft	@	6.75
12,000 cu. yd. of earth and loose rock excavation	@	3.50
210,000 cu. yd. of class "A" concrete	@	6.97
20,000 cu. yd. of class "B" concrete	@	7.40
12,000 cu. yd. of class "C" concrete	@	9.25
20,000 lb. of copper waterstops	@	.53
1,600 ft. asphaltum in contraction joints	@	1.73
2,000 barrels of cement for grout	@	7.20
Total cost of dam—approximately		$3,000,000.00

There is a bonus and penalty clause in connection with this estimate. It is desired to have the dam constructed to elevation 1050 as soon as possible in order to make some storage available for the lower power plant. The contractor receives a bonus of $1,000.00 per day for each day he completes the dam to this elevation sooner than 366 days from the day he was told to go ahead. He pays a penalty of $1,000.00 a day for each day he runs over this period.

It is desired to have the dam completed in 731 days and there is a clause in the contract providing for a bonus or penalty of $200.00 per day in this connection.

Gravel of a good grade is available within about 1000 ft. of the dam. At this place is also the terminus of a standard gauge railway built by the City of Seattle for hauling cement and other material to the dam site.

The major portion of the concrete in the dam contains 5 sacks cement per cubic yard but the upstream face of the dam to a depth of 4 ft. contains 6 sacks per cu. yd. The City of Seattle maintains a laboratory adjoining the construction camp and conducts sieve analyses of all aggregates. The exact proportion of the mix is determined as a result of these tests and careful

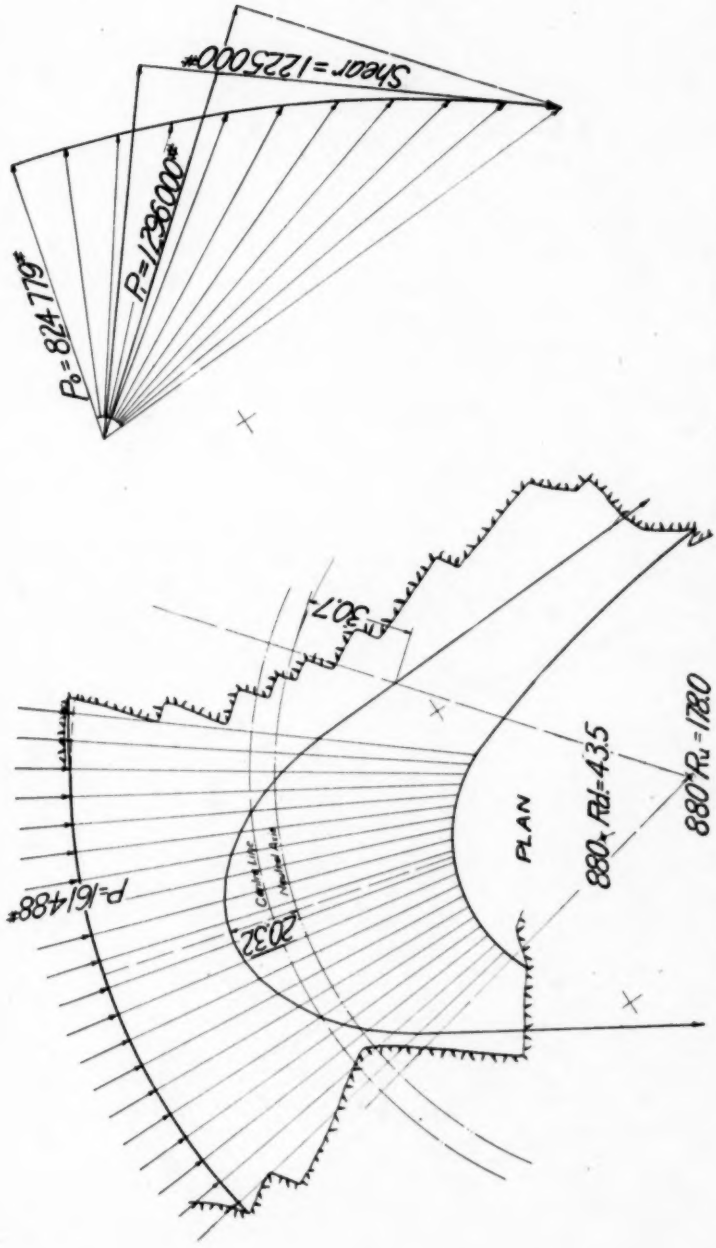


FIG. 16—DIABLO CANYON DAM. PRESSURE DIAGRAM FOR ELEVATION 880

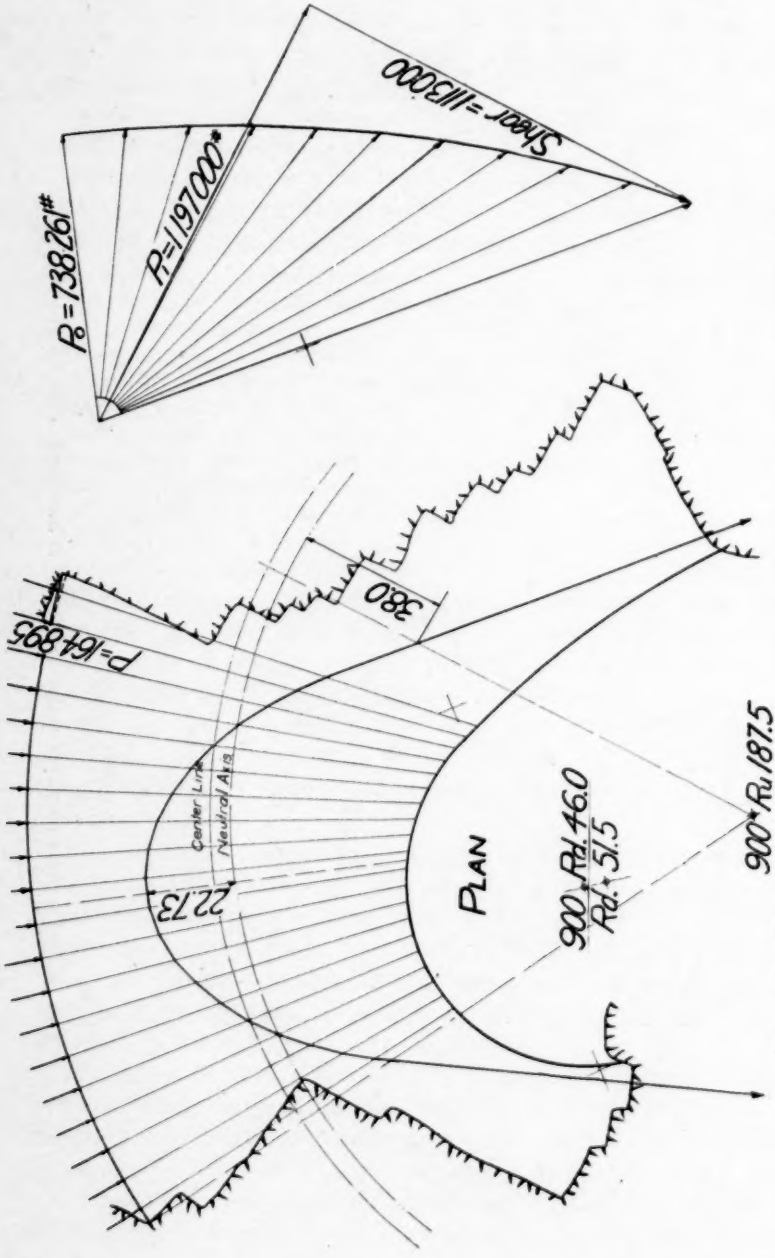


FIG. 17—DIABLO CANYON DAM. PRESSURE DIAGRAM FOR ELEVATION 900

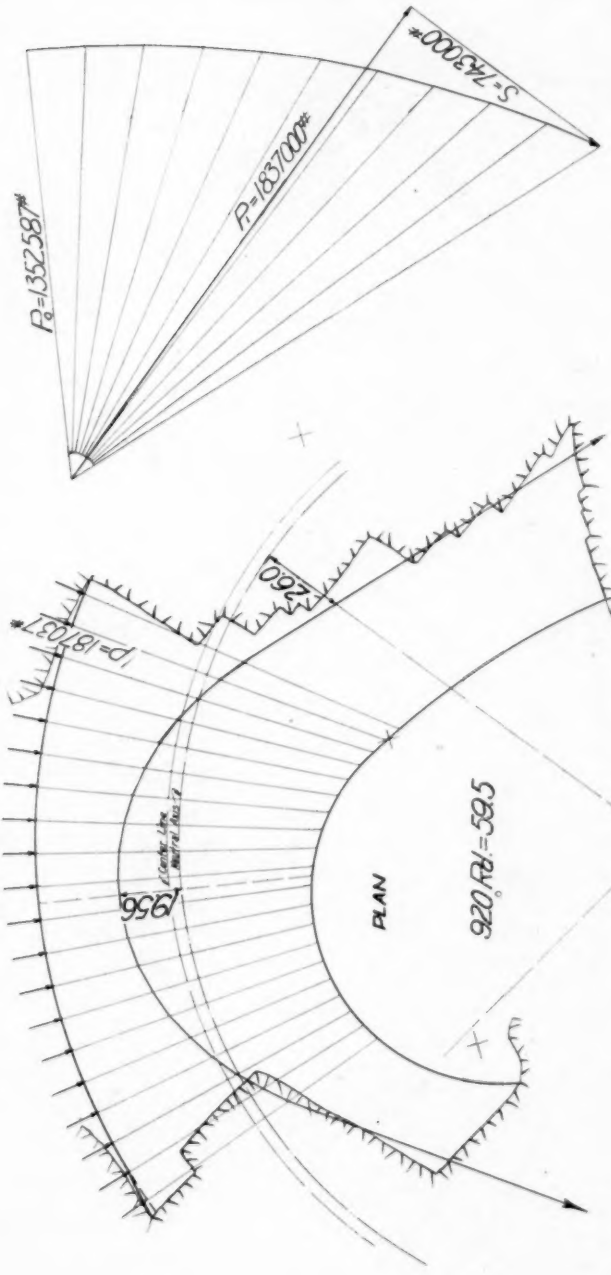


FIG. 18—DIABLO CANYON DAM. PRESSURE DIAGRAM FOR ELEVATION 920

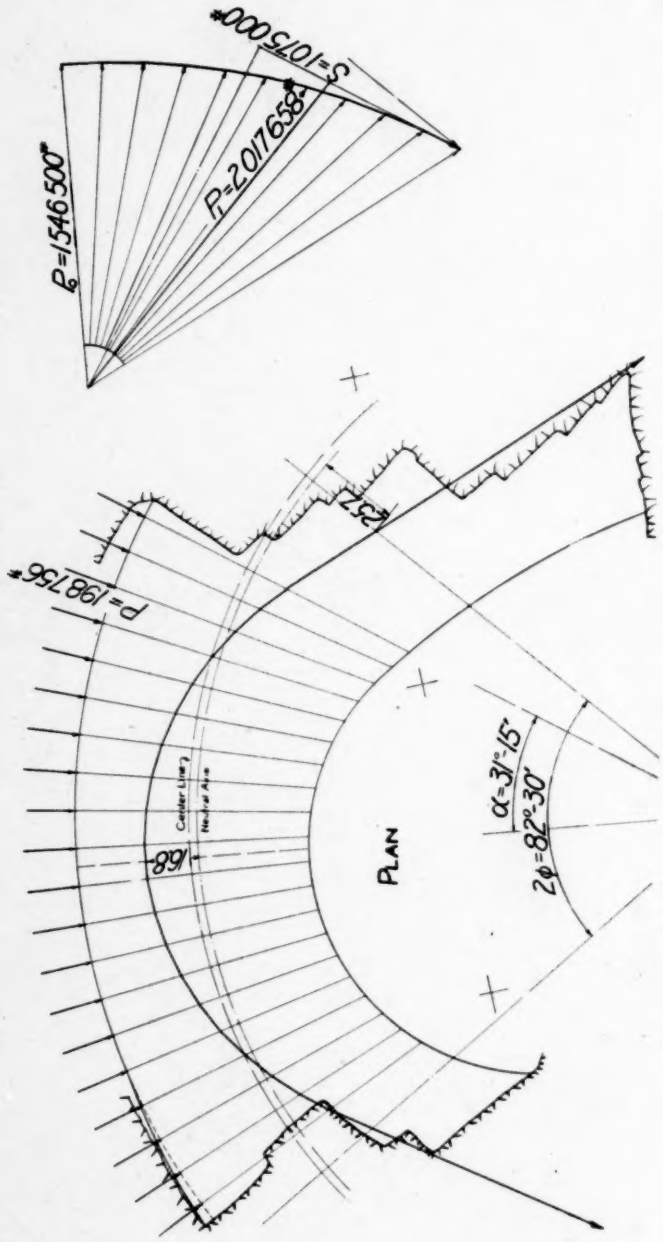


FIG. 19—DIABLO CANYON DAM. PRESSURE DIAGRAM FOR ELEVATION 940

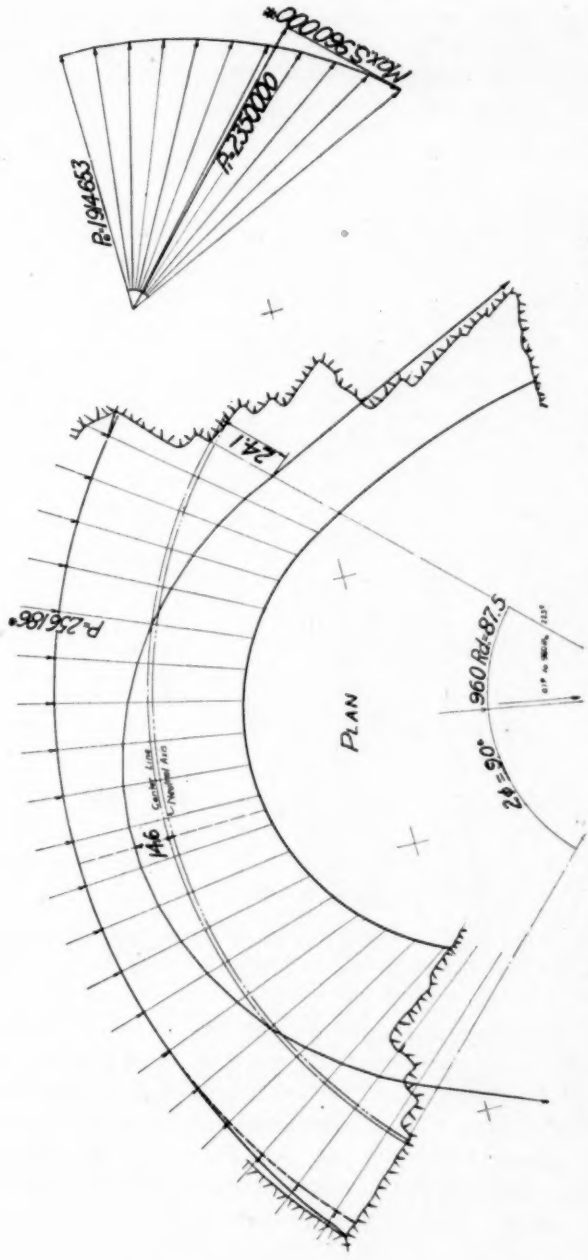


FIG. 20—DIABLO CANYON DAM. PRESSURE DIAGRAM FOR ELEVATION 960

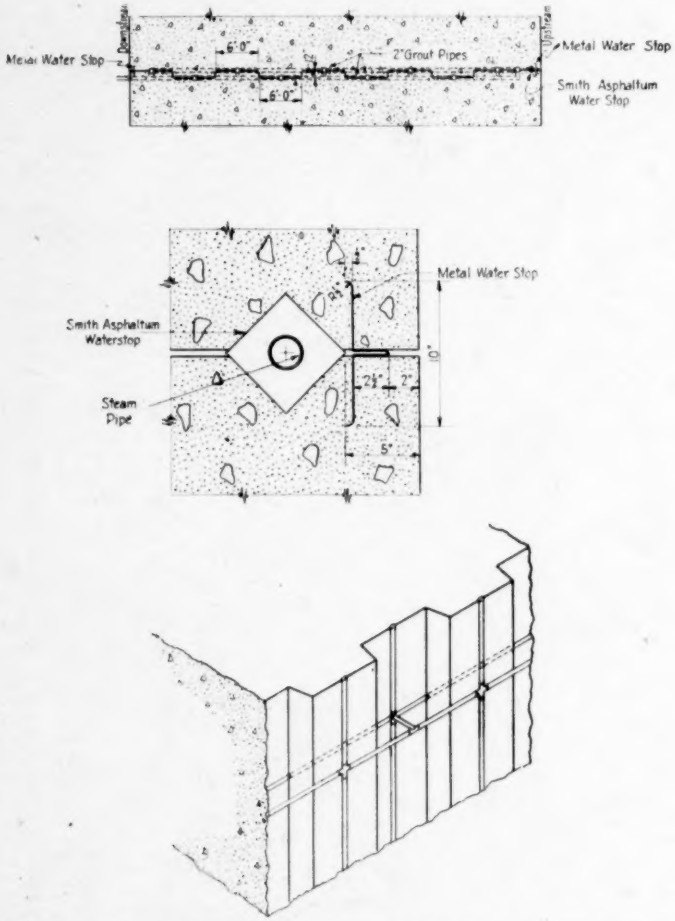


FIG. 21—DETAILS OF WATER STOP, DIABLO CANYON DAM, AND SKETCH SHOWING ARRANGEMENT OF PIPES

control is maintained over the water-cement ratio. As a result of the care in proportioning the mix and the exceptionally fine quality of the aggregates, the concrete develops high crushing strength in 28 days. The general average compressive strength in 28 days is about 4200 lb. per sq. in. The maximum compressive stress in any portion of the dam as computed by Cain's analysis is 599 lb. per sq. in.

The effect of swelling due to water soaking was investigated in connection with the design of this dam. The calculation of these stresses was made by use of the formulas derived by B. F. Jakobsen in his paper on "Stresses in Thick Arches of Dams" and published in Vol. 90 Trans. Am. Soc. C. E.

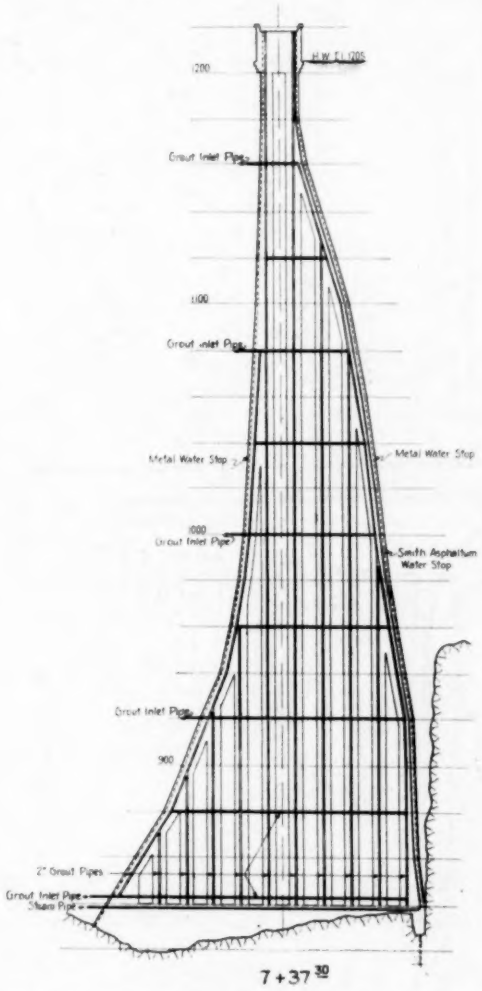


FIG. 21A—INSTALLATION OF GROUT PIPES AND WATER STOPS, DIABLO CANYON DAM

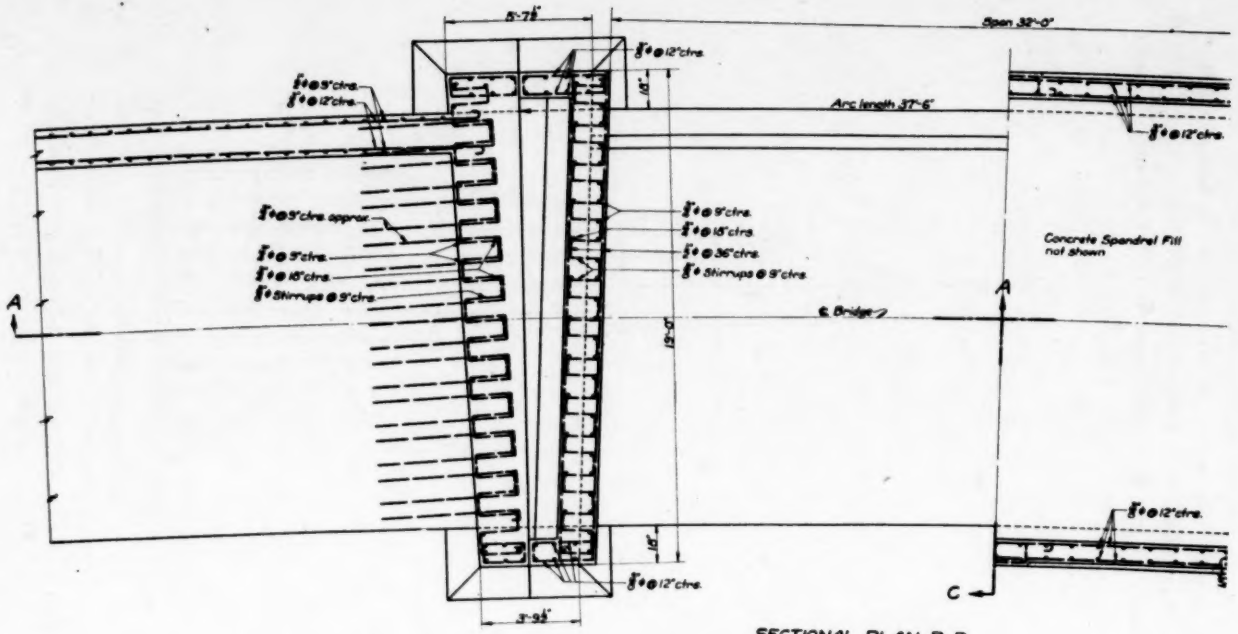


FIG. 22—DIABLO CANYON DAM. SECTIONAL PLAN OF ARCH BRIDGE

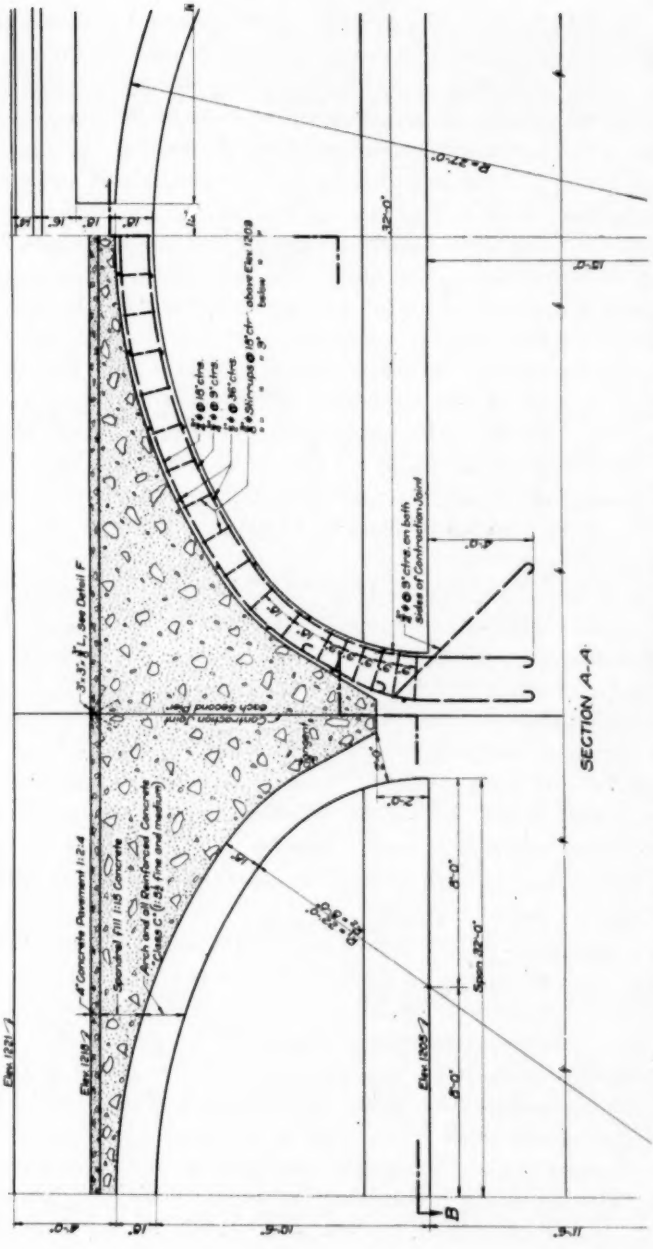


FIG. 22A—DIABLO CANYON DAM. DETAILS OF ARCH BRIDGE

For the Diablo Dam, the calculation of stresses due to swelling showed small increases in the compressive stresses at the crown section values of thickness divided by mean radius less than 0.25 and for ratios greater than 0.25, greater increase of compressive stresses at the extrados accompanied by a lowering of the compressive stress at the intrados, or if Cain's analysis indicated tension at the intrados, then an increase in the tension.

At the abutments the effect of swelling was much greater, the bending moments being large and of opposite sign to the moments due to water load on the arch. The general effect was to cause a very material decrease in compression at the intrados and an increase in compression at the extrados so that if Cain's analysis indicated tension at the extrados, the stresses due to swelling being of opposite sign, the resulting stress became compression.

For numerical values of all stresses in Diablo Dam and a detailed description of the dam and appurtenances refer to "Diablo Dam" by G. E. Goodall in Western Construction News, May 25, 1929.

The Constant Angle Arch Dam Co. furnished the design and acts as consulting engineers. City Engineer W. C. Morse, had charge of the development at the start. Later, W. D. Barkhuff was appointed city engineer and took over Mr. Morse's duties. T. H. Cover was his original assistant in charge of the work.

It is expected to finish this dam in the fall of 1930.

When looking back over the various structures described in the foregoing, it will be noticed that no regularity about the spacing of the contraction joints exists.

The writer has not yet found any spacing which he thinks is the best in general.

To be sure that no vertical cracks would appear between the artificial contraction joints, it would be necessary to have a joint every 40 ft. (or perhaps 50 ft. would still be safe). Since each joint costs a comparatively large amount of money the desire for increasing this distance is apparent and it will be noted that the spacing of the contraction joints on the dams illustrated in the foregoing is nearer twice 40 ft. than 40 ft.

On a "round" slender arch dam this spacing will generally still be safe, without any other cracks developing later, but on some of the heavier arches some chance of a vertical crack appearing

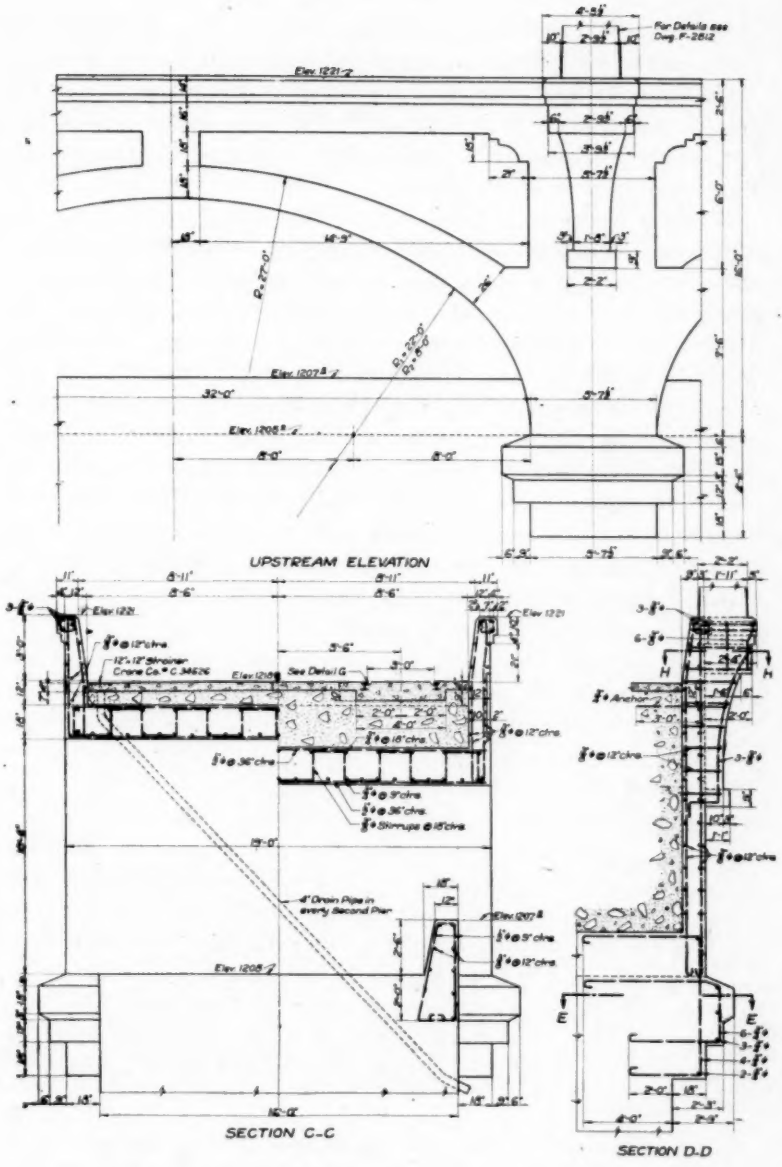


FIG. 22B—DIABLO CANYON DAM. DETAILS OF ARCH BRIDGE

between two contraction joints has been taken in order to lessen the joint cost. It is felt that such a crack will in each instance close water tight when the regular contraction joints are grouted.

On the Lake Spaulding dam previously mentioned such vertical cracks did appear very definitely, but the writer recalls but few other instances of pronounced cracks between artificial joints spaced over 50 ft. apart.

When a reservoir is filled for the first time, the dam or the foundation or mostly both will be found to leak some. Some of these leaks will close up by themselves but most of them will need grouting. It is not difficult to make a concrete dam and especially an arch dam commercially water tight by grouting. Theoretical water tightness can not be obtained, at least the writer has not observed this condition as yet, but it is important to carry on the grouting work to a considerable extent, when a dam is first put into use. The tighter the concrete dam the longer it can be expected to exist. Some owners or their engineers are rather reluctant in carrying out this process of water tightening after the structure is finished. They will go and look at some other dam, which leaks worse than theirs and then be satisfied with their own in a state not close enough to perfection.

It will perhaps be noted that temperature stresses have not been included in the calculations of the dams described. More importance is attached to the grouting of the contraction joints at a time when the dam body has its minimum temperature or at least as near the minimum as practicable. After this is done there can be no additional temperature stresses with water in the reservoir. With rising temperature the stresses will be less than calculated since the expansion due to the higher temperature will compensate in a measure for the rib-shortening whereby the bending stresses become smaller or may be entirely eliminated. If a reservoir is being filled gradually during the spring and early summer, it is not uncommon to observe the dam (arch dam) deflecting only about one third of what it would have deflected had the temperature remained constant and a minimum during the time of filling.

Readers are referred to the JOURNAL *for January, 1931, for discussion which may develop. Such discussion should reach the Secretary by December 1, 1930.*

Construction Specifications For Concrete Work on the Small Job

Proposed American Concrete Institute Specification No. 506

ARTHUR R. LORD,* AUTHOR-CHAIRMAN
Committee 506—Concrete Specifications for the Small Job.†

This proposed specification is unusual in conception and treatment. It may be read straight through on right-hand pages only, but is supplemented by "Specification Notes" appearing on left-hand pages and keyed to the specification proper by note numbers.—Editor

TO THE USER

This specification is intended for the use of Architects and Engineers, to be incorporated as a whole in the specifications for particular structures by reference in the proper place in the typewritten pages, and to become a part of the contract in the usual manner. It is intended for use on the *small job* on which full time inspection is not maintained, and it is based on the assumption that such work will be awarded by the Architect or Engineer *to honest contractors only* who can be depended upon to do high grade work without close inspection. This specification attempts to explain to the less experienced contractor, by means of numerous notes, why the work must be done in the specified manner. It assumes that poor concrete work on small jobs is due to lack of technical knowledge rather than to dishonesty and that the contractor, in preparing an estimate under such a specification as this is, will understand what is required of him to do good concrete work and will submit his bid on the basis

*President, Lord and Holinger, Inc., civil and architectural engineers, Chicago.
†Members: Theodore Crane, P. J. Freeman, S. C. Hollister, W. F. Way.

Specification Notes. (*See Specification Text Opposite*)

GENERAL NOTE ON CONCRETE MAKING

The major factor in determining the degree to which any concrete will develop strength, watertightness, and many other desirable properties, is the *ratio of the water to the cement* in the concrete as finally deposited in the forms. This basic relation was first reported by Duff A. Abrams in 1915, and has been exhaustively verified by many other experimenters. It has been shown to apply to concretes having strengths ranging all the way from 200 lb. per sq. in. to over 50,000 lb. per sq. in. Specification of concrete quality in terms of water-cement ratio (generally expressed as number of *gallons of water per sack of cement*) is now almost universal on larger work and is the only safe and intelligent basis of specification for small jobs also.

The time honored specification by loose volumes, e. g. one part cement to two parts sand to four parts gravel (or stone), is definitely obsolete; 1:2:4 concrete may develop a strength of 5000 lb. per sq. in. when used with a low water-cement ratio such as is employed in tamped paving bases, or it may develop less than 10 per cent of that strength when used with excess mixing water. The use of a *water-cement ratio* type of specification releases the contractor from fixed arbitrary proportions of sand and gravel (or stone). Under this type of specification the proportions of fine and coarse aggregate may be varied at will by the Contractor, during the time used to determine upon the mix to be used on any job, so as to produce the maximum economy obtainable without sacrificing the necessary ease in placing the concrete. This best proportion, as thus determined from trial batches (see Article 10), will vary widely with different fine and coarse aggregates and is rarely found to be in the old ratio of two to four.

A "philosophy" of concrete making—and what is more important, a practical comprehensive discussion of the entire subject—may be found in a small book by Franklin R. McMillan, "Basic Principles of Concrete making."*

Concrete is a mass of inert aggregates held together by hardened paste of portland cement and water. The properties of the paste—strength, water-

*McGraw Hill Book Co., $2.00. The following extracts from an abstract of this book (*News Letter*, JOURNAL OF THE AMERICAN CONCRETE INSTITUTE, Dec. 1929) indicate basic considerations developed fully in the book.

(*Notes Continued Page 68*)

of following these instructions, even though not forced by supervision to do so. While this is an unusual specification, as regards these explanatory and educative notes, it is obvious that the only assurance of quality on a job subject only to casual and occasional inspection lies in the character of the contractor himself. When the Architect or Engineer has discovered his honest contractor, it is believed that this type of specification will materially help in securing fine concrete work. If the contractor is dishonest, no form of specification will prevent poor work in the absence of effective and continual supervision.

The following wording is suggested to be used in the Architect's and Engineer's typewritten specification for individual buildings:

Specification for Concrete Work
Name and Location of Building
Name and Address of Owner
Name and Address of Architect or Engineer

All plain and reinforced concrete work on this structure shall be done in strict accordance with Specification No. 506 of the American Concrete Institute, which is hereby made a part of these specifications and which will be made a part of the contract for this work. All the provisions of Specifications No. 506 shall be in full force and effect, except as expressly modified or supplemented in the following special instructions for this structure.

(Here incorporate any clauses required or suggested by unusual conditions surrounding the work to be done.)

Wherever the words "Architect or Engineer" are used the same shall be construed to mean the Architect Engineer (strike out one) only.

This specification has been submitted to the following critic members of Committee 506, who have greatly assisted the author by their thorough cooperation and experienced criticism:

Theodore Crane, Professor of Architectural Engineering, Yale University, New Haven, Conn.

P. J. Freeman, Dept. of Public Works, Allegheny Co., Pittsburgh, Penna.

S. C. Hollister, Consulting Engineer, Swarthmore, Penna.

W. F. Way, Henry and McFee Contracting Co., Contractors and Engineers, Seattle, Washington

(*Specification Notes—Continued from Page 66*)

tightness, durability, etc.—determine the properties of the concrete. The quality of paste depends upon characteristics of cement; upon water-cement ratio; and upon time, favorable temperature and continued presence of water to complete hydration of the cement.

A plastic, homogeneous mixture is vital to good concrete making, meaning a mixture in which the constituent materials are evenly distributed in all parts of the mass as finally placed and hardened and one which, when freshly mixed, flows sluggishly but without segregation of water or fine materials from the coarse.

Plasticity depends upon relative quantities of paste and aggregate, upon plasticity of the paste itself, upon grading of aggregates and upon shape and surface characteristics of aggregate particles. The amount of paste must be sufficient completely to fill the voids in the aggregates and to float the aggregate particles. The paste must not be so diluted with water as to be unable to hold the particles in a cohesive mass nor so stiff as to make whole mass difficult to handle and place. Grading of aggregates determines quantity of paste required to float particles and also resistance to ready motion or flow of the aggregate itself. Shape of aggregate particles likewise affects the resistance to flow of the aggregate and of concrete made from it. Surface characteristics affect readiness with which paste surrounds and firmness with which it holds the particles and amount of paste required for plastic concrete.

A portion only of the water used in mixing concrete combines chemically with the cement—if only enough water were used to hydrate cement, concrete would be entirely unplaceable. Remainder of water—commonly the greater part of water used—makes it possible to handle the concrete but is also responsible for most of later difficulties. The greater the amount of uncombined water the less the water-tightness of the concrete. Additional curing causes more water to combine with cement.

Very great increases in strength are secured by continued curing. Curing is a major factor in concrete strength and its importance is not sufficiently realized on job. Age, with continued curing, shows consistent gain in strength following a W/C ratio law at all ages. The superiority of concrete with low W/C ratio over that with high W/C ratio increases with age.

A thorough study of this book will assist a Contractor to produce better concrete at no increase in cost.

Contractors who, for business reasons, deal entirely with one material dealer and who can obtain the same cement and aggregates on much or all of their concrete work, will do well to have experiments made to determine the water-cement-ratio-strength law for that particular combination of materials. For it must be recognized that the materials used affect the strength of concrete. In the absence of such advance tests the approximate strength of *well-cured plastic homogeneous concrete*, made from

(*Notes Continued Page 70*)

1. General conditions of the contract

This Contractor shall acquaint himself fully with the General Conditions of the Contract for this work. He shall be bound by all requirements of these general conditions insofar as they are applicable to his part of the work in the opinion of the Architect or Engineer. These General Conditions shall be made a part of the contract for the concrete work covered by this specification.

The Contractor shall read this Specification with the greatest care, taking into consideration all specification notes appearing herein, and shall carry on the work in accordance with the letter and spirit of this specification at all times without regard to the presence or absence of the inspector.

2. Scope of the concrete work

This Contractor shall provide all necessary labor and material and install complete, ready for convenient use, all portions of the structure specifically mentioned in these specifications and/or shown on the architectural or engineering plans or details of the structure, and also all usual necessary and essential portions of a structure of this type, that would commonly be made of plain or reinforced concrete, whether or not the same are definitely shown on the plans or listed in the specifications. In general the work of this Contractor shall include: concrete foundations; concrete floors on the ground, including fine grading and filling therefor; concrete retaining walls at building lines and area ways; concrete columns, roofs and floors; concrete walls; concrete or terrazzo floor or stair finish; any cutting, shoring, sheeting, hand excavation, backfilling or underpinning necessary to install concrete work properly; concrete sidewalks, paving and parking strips; installation of masonry ties or other inserts; concrete steps and stairways; concrete penthouses or tank supports; formwork for all concrete work requiring same; and so forth. This contractor shall also furnish and place all necessary reinforcing material, properly bent and marked, together with complete accessories to securely hold all reinforcement in its designed position during construction.

(*Specification Notes—Continued from Page 68*)

ordinary materials, may be taken as stated in article 10. Certain brands of cement develop strength much more rapidly than others, (*see Note 3*) and concrete made of them will have higher early strength. Crushed stone has been found to give higher strengths than gravel, with the same water-cement ratio. This apparent gain is almost exactly neutralized in the average case, however, by the fact that more paste is required to make crushed stone concrete workable than is required for gravel concrete. In much the same way finer aggregate seems to give higher strengths than coarser aggregate at the same water-cement ratio, but here again more paste is required to make the concrete thoroughly workable as the aggregate becomes finer.

For practical purposes the water-cement-ratio-strength law is limited, in its application to actual construction work,

(1) to plastic (readily placeable, not over-dry nor over-wet) mixes (see abstract reprinted above)

(2) to favorable conditions on the job that provide ample moisture in the concrete for the continued hydration of the cement (*see Note 11*)

(3) to favorable temperatures on the job. The rate of gain in strength of concrete is very much less at low temperatures than at high temperatures, becoming almost nil at temperatures below 40° F. (*see Note 19*).

Each subsequent note applies to that portion of the specification after which the same reference number appears.

Note 1

It is rarely possible to use sand from the excavation, on account of the high probability that dirt will become mixed with or may be already contained in it, in injurious quantities. This is a very frequent source of trouble, and aggregates from the site must not be used, except with the Architect's or Engineer's permission and only after exceptionally thorough tests.

Stone that deteriorates on exposure to the weather, or from pits or quarries where there is evidence of such deterioration, is unsafe to use.

Note 2

For sand for mortar topping (floors, sidewalks, etc.) not over 10 per cent shall pass the No. 100 sieve.

3. CONDITIONS AT SITE OF WORK

This Contractor shall visit the site of the work and make himself thoroughly familiar with all conditions affecting the conduct of his work, the location and arrangement of his plant, the storage of materials, and so forth. He shall make any necessary observations as to soil conditions, ground water level, sewers or public utilities, traffic requirements and so forth. No additional allowance of time or money shall be asked or granted because of this Contractor's lack of knowledge of conditions prevailing at the site at the time of estimating, or which may be readily foreseen to exist at the time that the work is undertaken.

4. CONCRETE MATERIALS

Portland cement shall be used for all concrete work. This cement shall be certified by the dealer to comply with all requirements of the standard specifications of the American Society for Testing Materials. (Serial designation: C9-26, or latest standard of this Society.)

Aggregate for this work shall be certified by the dealer (*See Note 1 opposite*) to comply with the following specifications:

Fine aggregate for this work shall consist of well graded natural or artificial sand, or other approved inert materials with similar characteristics, taken from sources that have furnished satisfactory materials for previous concrete work for several years, or if from a new source shall be thoroughly tested for soundness and permanence. It shall comply with the provisions of the Tentative Purchase Specifications for Concrete Aggregates, E5-A-26T, (or latest standard of the Institute) of the American Concrete Institute. In applying these provisions the sieve analysis of dried aggregate shall show as follows:

Passing No. 4 sieve—not less than 85 per cent.

Passing No. 50 sieve—between 5 and 30 per cent. (*Note 2 opposite*)

Passing No. 100 sieve—not more than 5 per cent.

Fineness Modulus—not less than 2.50

and the weight of clay and silt removed by decantation shall not exceed 3 per cent.

Coarse aggregate for this work shall consist of crushed stone, gravel, air-cooled blast-furnace slag, or other approved inert materials of similar characteristics, taken from sources that have

Note 3

This provision is essential for uniform concrete quality. Various portland cements and even the same brand of cement from different mills may vary in color, strength, rapidity of set, and workability. Changes in the character of grading of the sand, gravel or stone will cause variations (often large) in the workability of the concrete and in the amount of water required to produce a workable concrete on any particular job. Since both the strength and water-tightness of concrete depend on the ratio of water to cement, any changes in materials, resulting as they do in changes in water content, affect the quality and uniformity of the concrete to an important degree. Variation in kind of sand or gravel or stone may also affect the color and texture of the concrete and give a blotchy appearance. The Contractor's orders for materials for this work must include this requirement of a constant source and unchanging characteristics for the entire job.

Note 4

Cement will absorb water rapidly from the ground or even from the air on humid days. Water absorbed in this way hydrates the cement in the sack and destroys or greatly impairs its ability to make concrete. Cement must not be permitted to hydrate until the proper time—when it is placed in the mixer with the water, sand and gravel (or stone).

Note 5

Uniform concrete of specified quality can only be made by accurate measurement of each ingredient and by the continued repetition of this measurement in each successive batch. If the sand and gravel piles are permitted to overlap it is not longer possible to accurately measure either material. With too much sand the concrete becomes too stiff, while if water is added to restore its workability, the strength is reduced. With too much gravel or stone the concrete becomes too wet and tends to separate, the mortar running away from the stone. This results in concrete of uneven quality and also frequently in sand streaks or stone pockets and the extra cost of patching.

Gravel or stone piled up carelessly tends to separate, the coarser particles running down outside to the bottom of the pile.

(*Note 5 Continued Page 74*)

furnished satisfactory materials for previous concrete work for several years or if from a new source shall be thoroughly tested for soundness and permanence. It shall comply with the provisions of the Tentative Purchase Specifications for Concrete Aggregates, E5-A-26T (or latest standard of the Institute) of the American Concrete Institute. In applying these provisions the sieve analysis of dried aggregate shall show as follows:

Passing 1-inch sieve—not less than 95 per cent.
Passing No. 4 sieve—not more than 10 per cent.
Passing No. 8 sieve—not more than 5 per cent.
Fineness Modulus—between 6.30 and 7.50.

The weight of slag shall not be less than 65 lb. per cu. ft. The weight of soft, friable, thin, elongated or laminated pieces shall not exceed 3 per cent.

Aggregates shall be so stored and handled at all times as to remain separate from each other and free of all foreign material until placed in the mixer. (*See Note 5*) Drainage shall be provided where necessary to avoid accumulation of water in aggregates.

Water shall be taken from the usual drinking supply and shall be paid for by this Contractor.

The same materials shall be used throughout the work, including the same brand of Portland Cement from the same mill, the same sand and gravel or crushed rock from the same source and from the same bin at the screening plant. (*See Note 3*) This Contractor shall be fully responsible for the correct certification of all materials by the material dealer, as provided above. In case of doubt this contractor shall pay for the necessary tests to be made under the direction of the Architect or Engineer.

5. Storage and handling of materials on the job

Cement shall be stored in a weather tight shed or building if kept on hand more than three days. If used promptly, it may be stored on a platform raised above the ground or so stored or handled as not to permit it to take up moisture before being placed in the mixer. All the cement in any container, in which part of the cement has become caked or has otherwise deteriorated, shall be entirely removed from the work. (*Note 4*)

Sand and gravel (or stone) shall be kept entirely separate from each other, until placed in the mixer. (*Note 5*) They shall be

(Note 5 Continued from Page 72)

When this has occurred the effect is similar to that of mixing the sand and gravel. When all coarse particles are used for gravel, the concrete becomes too wet. When all fine particles are used the concrete becomes too stiff. In either case the uniformity of the concrete is lost, the cost and labor of placing the concrete is increased, and the value of the finished work is impaired. The stock piles should be placed and removed in horizontal layers and all sliding or rolling particles in the piles avoided as far as possible.

Note 6

On the Pacific Coast and in one or two cities elsewhere, structural grade new billet steel may be used, provided the Engineer's approval is secured. Higher stress is permitted on intermediate grade new billet steel or on rail steel than on structural grade new billet steel and this substitution can only be made when the stresses used in the Engineer's design are suitable for structural grade steel. In other parts of the United States, the dealers in reinforcing materials have standardized on the two grades of steel mentioned in article 6 and no other grade is available except on special mill order.

Note 7

No dependence can be placed on the long discredited practice of lifting the bottom steel off the forms, as the concrete is placed, and depending upon the concrete or on pebbles or stones taken from the concrete and placed under the bars, to keep the bars up. Properly designed, rigid supports must be provided and completely placed before concreting is started.

The strength of a reinforced concrete structure, and frequently its fire safety also, depends on the placing of the steel at its designed location as shown on the plans. The load on a chair is frequently very heavy, as when a heavy man carrying one end of a runway steps upon it. Chairs and spacing devices made of soft steel or of too light section, are readily flattened down or bent out of shape. Such devices must not be used, as they only give a false sense of security and the money spent for them is largely wasted.

Note 8

This Contractor should allow in his estimate for a small supply of ⅜-in. round bars which will be available for filling in

(Note 8 Continued Page 76)

stored in bins or dumped only on clean platforms or pavements, and no dirt, rubbish or other foreign material shall be permitted to mix with them. In dumping gravel or stone the various sizes of particles shall not be permitted to separate, but the mass must be kept well graded at all times. (*Note 5*)

6. Reinforcing steel and inserts

All reinforcing steel for this work shall be furnished and placed by this Contractor. All bars shall be of intermediate grade new billet stock or of rail steel, meeting the standard specifications of the American Society for Testing Materials (Serial Designation: A 15-14 or A 16-14). (*Note 6*) All bars shall be supported at the proper height and at the proper spacing as shown by the drawings, using precast concrete or metal chairs, spacers and supports to hold them securely in place. (*Note 7*) Metal chairs, spacers and supports shall be made of stiff springy steel of such strength as not to be flattened out or be displaced by workmen. (*Note 7*) All reinforcement as used shall be thoroughly cleaned of mill or rust scale and of coatings of any kind that will destroy or impair the bond between concrete and steel. All reinforcement shall be carefully formed to the shapes and dimensions shown on plans. Tie wire shall be soft annealed iron wire not smaller than No. 18 gauge.

All bent bars, ties and stirrups shall be tagged with metal or other persistent identification marks to insure their location in the proper part of the structure as shown by the drawings. Heating of reinforcement or rebending of bars will be permitted only when the entire operation is approved by the Architect or Engineer.

All portions of the concrete work shall be provided with reinforcement (unless resting directly on firm, undisturbed ground.) Any gaps in the reinforcement as shown on the plans shall be suitably filled, using not less than $\frac{3}{8}$ in. round bars at 6 in. on centers in one direction in any case. (*Note 8*)

7. Formwork

Forms for this work may be made of wood, steel or other material which has been satisfactorily used on similar work for this purpose. Where panel forms are re-used they shall be thor-

(*Note 8 Continued from Page 74*)

gaps as specified. By the term "gap" is meant a *small* unreinforced area such as sometimes occurs between pipe sleeves, or where the regular groups of parallel bars leave a small triangle between them. Any unreinforced space above 5 sq. ft. in area, or extending for any considerable distance should be promptly called to the attention of the Architect or Engineer and a request made for instructions.

Note 9

Wooden formwork tends to dry out and to open up cracks between the boards. Dirt gathers in these cracks and when the forms are wetted, either by rain or in preparation for concreting, the dirt prevents the cracks from closing and as a result, the surface of the finished concrete shows a succession of unsightly ridges where the mortar has filled these open cracks. The swelling of the forms also causes movements at the sides of the building, at elevator and stair openings, etc., and requires expensive cutting to plumb up the walls and shafts. This cutting may reduce the fireproofing or even expose the steel to rusting. All this can be easily and inexpensively prevented by the simple expedient of keeping the formwork always damp, as specified.

Note 10

It is much better to cut a hole of the size of the end of a 4x4 or a 6x6 and build in a shore in advance so as to bear directly on the concrete, than it is to remove the forms and then "re-shore" (put in new posts), wedging the same against the new slab. Re-shoring operations permit the slab to sag and then force it back again to an undetermined amount. Slabs have frequently been weakened or even cracked by re-shoring and this practice should be entirely discontinued. Built-in shores must be selected so as to have sufficient stiffness to support their load after the bracing has been removed with the regular formwork.

oughly cleaned and repaired to produce a true, even surface. All forms shall be mortar-tight and sufficiently rigid to prevent sagging between supports. Surfaces of metal forms shall be free of marked irregularities, dents or sags. Knotholes or broken places in wood forms shall be covered with metal patches. All formwork shall be so designed (cleanout openings at base of columns, at bottoms of deep girders, etc.) as to permit of ready cleaning and inspection after the reinforcement has been placed. For spans in the structure in excess of twenty feet, the bottoms of beams, or girders, shall be cambered, allowing one-twenty-fourth of an inch rise per foot of span. Joints in formwork shall be either horizontal or vertical. All interior angles not occurring on an exposed face of the structure shall be formed with a one-inch bevelled fillet, unless otherwise called for on plans.

Wooden formwork shall preferably be kept continually moist after being erected, so as to prevent the opening up of cracks in which dirt may lodge. (*Note 9*) Paraffin or other suitable formwork oil shall be applied to forms immediately before the reinforcement is placed. In no case shall the oil be permitted to coat the reinforcement. No oil shall be used where the concrete surface in contact with the formwork is later to receive plaster. Concrete shall be placed as soon as possible after the reinforcement has been placed and inspected, so as to prevent the collection of dust and dirt on the oiled formwork.

The design of the formwork shall include all necessary shores built in place in advance of concreting in cases where portions of the forms require to be removed before the concrete on them is ready to support itself. These shores shall not be disturbed in the removal of the adjacent formwork. No re-shoring will be permitted. (*Note 10*) Formwork supports shall be trussed as necessary for stability and to prevent settlement when foundation conditions for shores are bad. Where internal ties are necessary bolts or rods shall be used; they shall be so arranged that no metal shall be left within one inch of the surface of the concrete. All holes left by the withdrawal of these bolts or rods shall be neatly patched. Tie wires will be permitted only for concrete members entirely protected from the weather (or other corrosive exposures) and only by especial permission of the Architect or Engineer.

Note 11

The rapidity with which concrete gains in strength depends on several factors, which must be considered in connection with removing form work. Certain portland cements give a higher strength at early ages than others. Concrete gains strength much more rapidly at high temperatures than at low temperatures. Stiff concrete gains strength more rapidly than sloppy concrete. Concrete must have moisture in order to maintain its increase in strength, and concrete from which moisture has been rapidly evaporated within a few days after placing may be expected to be weak and leaky. On any particular job the temperature since the concrete was placed is most important, while the other items mentioned are important in case any doubt exists as to the wisdom of removing form work.

Note 12

Accurate measurement, providing the same amount of each material in every batch, will result in concrete of the same workability and will make all the operations of mixing, transporting, and placing concrete, as simple as possible. Inaccuracy of measurement will cause variation in the consistency of the concrete with corresponding uncertainties in the mixing, transporting, and placing and will result in concrete of unequal strength, water-tightness and quality. Stoppages in the chutes, with their attendant mess and expense, are commonly due to variations in measurements (or in grading) that result in a too-stiff batch that sticks, or a too-wet batch that races. All such troubles may be readily avoided by careful control of the materials (see note 5, page 72) and consistent accuracy of measurement.

An experienced workman shall be employed at all times during the placing of concrete to watch the formwork and its supports and to strengthen any portions that may show signs of sagging, displacement or failure.

8. Removing formwork

This Contractor shall be solely responsible for the safety of the construction during and after form removal, and no act of the Architect or Engineer or of his representatives on the work shall relieve this Contractor of such responsibility. Subject to this limitation, and measured in days of good curing temperatures (not less than 60° F., twenty-four hour average), forms for columns shall not be removed in less than one day; forms for slabs or other members whose span does not exceed five feet nor eight times their depth and which carry only their own weight (or in which all super-imposed loads are adequately supported by built-in shores [*Note 10*]), shall not be removed in less than three days. Other forms shall not be removed in less than seven days. At average temperatures, lower than 60° F., a longer period shall elapse sufficient to produce the same strength of concrete. (*Note 11*)

9. Patch formwork

Forms for patches (where temporary openings have been left for any reason) shall be rigidly supported, being posted from the floor below or suspended by rods or bolts and not hung by twisted wires or other means that will permit displacement of the patch formwork, and unsightly surfaces.

10. Measurement of the batch

Job measurements shall be so made as to insure that each successive batch of concrete is made up of identical volumes (or weights) of cement, water, sand and gravel (or stone). (*Note 12*) Each batch shall be proportioned to use only whole sacks of cement, unless a suitable container is provided to measure accurately the required amount of cement from broken sacks, or unless the required amount of cement is determining by weighing on the job. Sand and gravel or stone may be measured in measuring boxes containing the required volume for one batch, such boxes being struck off level full at each use, or any equivalent accurate method may be used. At least one wooden box

Note 12A

In this specification the *water-cement ratio* is the fixed requirement. The strengths given are based on the usual experience with average materials. The Architect or Engineer, under this specification, does not require this strength, but he does reserve the right to require the use of other common and readily available materials, in place of those selected by the Contractor, should the latter prove to be exceptional and to result in lower strength than that intended. The approximate mixes are likewise not binding upon the Contractor, who is free to use as much aggregate as he can while maintaining the specified water-cement ratio and a workable consistency.

of one cubic foot capacity, with handles, shall be provided for checking volume measurements. Unless weighed or measured in an accurate measuring tank, water shall be measured in a pail with a line painted on it to give the proper water level at each filling.

The proportions of cement, water and aggregate (sand and gravel) shall be taken as follows:

Class A concrete, requiring a strength of approximately 2000 lb. per sq. in. at 28 days, shall be made with 7.5 gallons of water per sack of cement. The approximate ratio of the volume of the cement to the sum of the combined volumes (measured separately) of the sand and gravel (or stone) will be 1 to 5.75 (*Note 12A*) Unless otherwise noted on the plans, all concrete will be Class A concrete.

Class B concrete, requiring a strength of approximately 2500 lb. per sq. in. at 28 days, shall be made with 6.75 gallons of water per sack of cement. The approximate ratio of the volume of the cement to the sum of the volumes of the sand and gravel (or stone) will be 1 to 5. (*Note 12A*)

Class C concrete, requiring a strength of approximately 3000 lb. per sq. in. at 28 days, shall be made with 6 gallons of water per sack of cement. The approximate ratio of the volume of the cement to the sum of the volumes of the sand and gravel (or stone) will be 1 to 4.25. (*Note 12A*)

Equivalent weights may be used in place of volume measurements for all classes.

In determining the amount of water, allowance shall be made for the free (surface) water on the aggregate. In the absence of job tests, sand shall be considered to carry 0.25 gallons of surface water per cu. ft. if damp, and 0.8 gallons per cu. ft. if wet. Gravel or stone shall be considered to carry 0.15 gallons per cu. ft. if damp, and 0.5 gallons per cu. ft. if wet.

Trial batches shall be made on the job to determine the final volume (or weight) of sand and gravel (or stone) to be used. The water-cement ratio shall not be changed but the amount of aggregate shall be increased or decreased to give the proper workability of the concrete as specified in article 11. The division of the aggregate between sand and gravel (or stone) shall be

Note 13

Sand and gravel (or stone) may be considered as fillers in the concrete, the quality of the concrete depending primarily on the water-cement ratio, which determines the quality of the "paste." Variation in this proportion of sand to gravel (or stone) affects the workability of the concrete greatly and the trial batches should cover a considerable range so that the best proportion for the economical transporting and placing of the concrete may be selected. The limiting proportions given here are determined from experience with a very wide range of materials.

determined by trial so as to give the most workable and non-separating concrete, but the volume of sand shall not be less than one-third nor more than one-half of the total volume of the sand and gravel (or stone) measured separately. (*Note 13*)

11. MIXING CONCRETE

Concrete shall preferably be mixed in a power driven rotary batch mixer. In no case shall the capacity of the mixer be less than a one sack batch and a large mixer with a capacity of two or three sacks of cement (with the corresponding quantities of water, sand and gravel (or stone) shall be provided except on very small jobs. Other devices, mixing concrete equally well, may be used with the consent of the Architect or Engineer. The capacity of the mixing equipment shall be such as to produce all the concrete required at any one level above the foundations in a single working day. In case of very large areas to be built at a single level this requirement may be waived by the Architect or Engineer.

Mixing equipment shall be cleaned at frequent intervals so as to keep all parts operating efficiently. Batch mixers shall be fully discharged before the next batch is admitted to the drum. Concrete which has partially hardened shall not be remixed with added water. Such concrete shall be wasted.

The requirements of Article 10 apply equally to hand mixing when this is resorted to for small quantities of concrete. Hand mixing shall be done in a clean, watertight, mortar box or on a level, watertight, clean wood, metal of concrete floor or platform which has been thoroughly wetted to prevent absorption of water from the concrete. The sand shall first be spread in a layer of uniform thickness on the mixing platform. The gravel or stone shall then be placed on top of the sand in a second layer of uniform thickness and covering the entire first layer. The two layers shall then be turned and mixed with shovels for at least three complete turns and until the mixture is uniform in color and appearance. The mixture shall then be levelled off and the cement spread in another layer of uniform thickness over the entire mass. This shall then be turned with shovels for at least three additional complete turns and until the mixture is uniform in color. The material shall then be levelled off, depressions

Note 14

Hand mixing of concrete is generally prohibited, not because a satisfactory concrete cannot be made by this method, but because the work is often done in a careless and lazy manner. This Contractor and his superintendent on the job must give personal attention to hand mixing operations, training a crew of men to do the work systematically and thoroughly and affording them time to carry out these specifications properly. Each "turn" must handle *all* of the material and there must be a clear gap in the pile (up to the time that water is added) between the portion turned and that not yet turned on each operation. Thus the pile moves bodily to the left at one turn and back to its original position at the right on the next turn, etc. The platform or mixing box must be of sufficient size to permit of this movement for a full batch. Much skill is shown by some workmen in securing a thorough mixing of the materials, by the proper twist of the shovel, and also much skill in working the water into the mixed cement, sand and gravel (or stone) evenly, and without permitting any to escape. Workmen showing such skill must be employed at this work in preference to those without it.

Note 15

The greatest economy, resulting from the use of more sand and gravel (or stone) with the same amount of cement and water, will be found with the stiffer consistencies. Too stiff a consistency will increase the difficulties of placing, however, unless the concrete can be tamped in placing. In the case of footings or of floors laid on the ground, very stiff concrete, consolidated by tamping, is permissible and economical. The sloping portions of footings may be built without forms in this way. Since the water-cement ratio is definitely fixed, and the consistency limited by these specifications, the greater amounts of aggregate necessarily involve stiffer concrete.

The consistency of concrete, made from any fixed set of materials, may be judged by the slump test, using a truncated cone-shaped mold as described in the A. S. T. M. specification D 138-2-T. This device is especially useful in case the moisture in the aggregate varies rapidly (as after rainy weather), to de-

(Note 15 Continued Page 86)

shall be made in the surface uniformly distributed and of sufficient size to hold all the mixing water for the entire batch and this water shall be poured into the depressions to give as near uniform distribution as possible. With the shovel, work the ridges of mixed cement and aggregate so as to take up all the water without letting any escape, and then turn the mass with shovels for at least two additional complete turns and until it is uniform in consistency. (*Note 14*) Only enough water shall be used to give a quaking, jelly-like mass, from which the water will not separate and run out on the platform, after mixing is completed.

The consistency of the concrete when mixing is completed, shall be such that the concrete flows slowly with a rounded edge, and without any visible separation of the water or of the mortar from the gravel or stone. For concrete to be placed in thin walls or about congested reinforcement or in other difficult places, the rounded edge may be permitted to be quite thin, while for concrete placed on a level deck with very little steel the concrete should be as stiff as possible while still showing a decided tendency to flow. (*Note 15*)

12. Time of mixing

One full minute shall elapse between the time when all the material for any given batch is placed in the mixer and the time when the first concrete of that batch is discharged from the mixer, except that a portion of the mixing water may be introduced during the first ten seconds of the mixing time.

13. Conveying concrete

The consistency of the concrete at the completion of mixing, as specified above, shall be maintained during the transportation of the concrete from the mixer to the forms. The methods used by this Contractor on this work shall be such as to comply fully with this requirement. (*Note 16*) Separation of the mortar from the coarse aggregate shall not be permitted at any stage.

14. Placing concrete

Before commencing the placing of concrete all formwork shall have been thoroughly washed (*Note 17*) and shall be clean and free from construction dirt and debris, all reinforcement shall be properly placed and supported and all inserts and openings shall be completely installed for a distance of at least thirty feet ahead

(*Note 15 Continued from Page 84*)

termine quickly and accurately the change in mixing water required to keep the specified consistency.

Note 16

Chutes may be used in transporting concrete provided the results on this work at all times meet the requirements of article 13. It is possible to use chutes so that this is done, but it is all too common that failure results in the attempt. Chutes must be sloped at just the right angle to cause the concrete to flow without separation. A hopper must be provided at the end of the chute and the concrete wheeled or shovelled from this hopper into the forms; the only permissible exception (permitting concreting direct from the chute) being where concrete is placed in a large mass, as in a footing, where there is no chance for it to flow out to a thin edge and to separate. Carts or wheelbarrows will be used more commonly on jobs of the small size covered by this specification.

Note 17

Even in freezing weather the formwork should be cleaned with water or steam, as this is the only practical means of removing the loose dirt. If the temperature is sufficiently high for the proper placing of concrete under this specification, the water will not freeze.

Note 18

On small jobs it is even easier than on large ones to change frequently from concrete to "grout" and so keep the mortar always fresh and soft when the concrete is placed. In hot, dry weather, especially, good judgment must be used in the timing of mortar batches, as in such weather the thin edges of the mortar dry quickly and there is a tendency for such dried edges to scale off later. For this reason the consistency of the mortar should always be such that it flows with a slightly rounded edge. The amount of water to be used to give this consistency is readily determined by trial.

Where the steel is very congested, as in thin walls, so that the concrete is separated by hitting rods repeatedly as it falls, this difficulty may be readily overcome by using a portable metal

(*Note 18 Continued Page 88*)

of the concreting operation on all sides. Runways shall have been placed and the resulting dirt cleaned up and any steel disturbed shall be properly replaced. Column capital forms or other depressions at which the washing water may gather shall be drained and the concrete shall not be deposited in standing water. In weather requiring heating of the fresh concrete in place, the salamanders or other heating devices shall be in operation before concreting starts. No snow or ice shall be left in any part of the forms.

In columns, or similar slender vertical or slightly inclined members, the bottom shall be filled with mortar (concrete from which the coarse aggregate and much of the usual water has been omitted) which shall be sufficient in quantity and proper in consistency to work up with the concrete and to fill all spaces between closely spaced bars or between the steel and the formwork. In girders or other similar members, in which the congestion of steel makes placing difficult, the lower part of the forms shall be filled with mortar in the same manner. This mortar, in either case, shall be placed immediately in advance of placing the concrete and shall not be permitted to dry out or set so as to lose its mobility before the concrete is placed on top of it.

Concrete shall not be dropped through reinforcing steel (as in walls or beams with top reinforcement) so as to cause separation of the coarse aggregate from the mortar on account of repeatedly hitting rods as it falls. In such cases hoppers, and, if necessary, vertical ducts shall be used in the wall forms or on the outer face of the wall forms, (*Note 18*) or other means employed so that the concrete may reach the place of final deposit without separation. Concrete shall be deposited in small amounts at many points and shall not be required or permitted to flow along the forms for more than a very short distance, or from beam forms into column or wall forms.

Concrete shall be worked around the reinforcing rods, inserts, etc., and against vertical forms as it is being placed, so as to produce smooth, dense, surfaces and complete filling of all spaces within the forms but care shall be taken not to over-spade the concrete so as to cause segregation locally. Concrete being placed with a very stiff consistency (as in paving base or in sloped foot-

(Note 18 Continued from Page 86)

duct with a hopper top that may be inserted inside the form so as to conduct the concrete past the bars, or when the space between bars is very small, wooden ducts may be built by housing in the space between adjacent studs and cutting openings through the side form to admit the concrete below the steel. A duct 3 in. to 4 in. wide by 16 in. to 20 in. long in cross section is adequate for this purpose. In the case of the outside wooden duct a baffle fastened to a long handle should be lowered inside the forms and placed directly opposite the opening in the form and close up to the form to prevent the concrete from segregating as it flows through the hole.

ings concreted without forms) shall be consolidated by tamping or vibration of the concrete or by vibration of the forms (never by vibration applied directly to the reinforcement).

15. Construction joints

All the concrete in vertical members (such as columns or walls) shall have been placed at least two hours before any concrete is placed in the beams or slabs directly over such columns or walls. This interval may be increased if desired (over night, for example) but necessary precautions shall be taken to insure that the new concrete bonds to the older concrete, if the interval exceed thirty hours, or if the weather is hot and drying. In any case, any excess water or fines that may rise to the top at a horizontal construction joint, shall be removed and the concrete cut away as necessary to insure strong, dense concrete at the joint.

Construction joints in beams and slabs shall be vertical and shall be located close to the center of the span, unless a beam intersects a girder at this point, in which case the joint in the girder shall be offset a distance equal to twice the width of the beam and inclined reinforcement provided to take the shear across the offset construction joint. Construction joints shall be made with a key at the center of depth and with reinforcement near each face of the member, additional bars, at least 60 bar diameters in length, being provided where steel is lacking in either face of the member cut by the construction joint. The added bars shall have a cross sectional area not less than .0025 of the area of the member cut by the construction joint. The member of construction joints in beams and slabs shall be kept to a minimum. (See article 11—capacity of mixer required.)

16. Placing against hardened concrete

Before depositing new concrete on or against concrete which has set, the forms shall be retightened, the surface of the set concrete shall be roughened as required by the Architect or Engineer, thoroughly cleaned of foreign matter and laitance, and saturated with water. The new concrete placed in contact with hardened or partially hardened concrete, shall contain an excess of mortar to insure bond, and shall not be placed until the saturated surface has become dull (but not lightened in color) through absorption or removal of all excess water.

Note 19

Watertight concrete can readily be obtained without the use of any admixture or compound. The concrete must be so proportioned as to have sufficient mortar to fill all the voids in the gravel (or stone), which is also a requirement for good workability and easy placing. If, then, the concrete is held to the consistency specified above and placed with care to prevent segregation (stone pockets or sand streaks indicate bad segregation and careless work) the concrete will be watertight when the cement is properly hydrated. It is the experience of investigators that almost all usual concrete mixes produce waterproof concrete under laboratory conditions. The difficulty in the field probably arises largely from segregation during transporting and placing of the concrete and from joints where the concrete is not made to bond properly. (See article 16.) The process of hydration requires favorable conditions—warmth and moisture always present—and a reasonable length of time. The strength as well as the water-tightness is greatly improved by long, warm, moist curing. Warmth without moisture simply dries out the concrete and all gain in strength or water-tightness ceases in dry concrete. Moisture without warmth is equally useless or may be harmful if freezing occurs. Below 40°F concrete is practically dormant. It is important also that concrete is provided with both warmth and moisture when it is young, as the chemical activity decreases with age.

Note 20

Concrete deposited in a trench or on the ground can be "effectively enclosed" by a covering of hay on all exposed surfaces or by laying a tarpaulin over the trench and covering it with hay. Concrete in large masses develops ample chemical heat for its own curing, provided this heat is prevented from escaping. In elevated work, the problem of effective enclosure is more difficult, and care must be taken with the usual enclosure of tarpaulins (heated with salamanders) to properly support the tarpaulins with timber to prevent openings in windy weather and to keep the tarpaulins away from the surface of the concrete at edges of a floor. The arrangement must be such as to provide warm air surrounding

(*Note 20 Continued Page 92*)

17. DEFECTIVE CONCRETE

Any defective work discovered after the forms have been removed, which in the opinion of the Architect or Engineer cannot be repaired satisfactorily, shall be removed at once and replaced. No compensation will be allowed for patches or replacements because of defects. Defects shall include honeycombing, or other surface blemishes; or portions which through lack of uniformity in the concrete render them, in the opinion of the Architect or Engineer, inadequate in strength; or improper alignment of outside or exposed faces.

Patching where permitted shall be done only under the supervision of the Architect or Engineer. The cavity to receive the patch shall be wetted thoroughly and allowed to stand sufficient time for the surface of the cavity to become dull but not lightened in color. The patching material shall be of the same material and in the same proportions as the concrete receiving the patch. It shall be worked into place in a dry consistency and shall be thoroughly rammed. The patch shall be built up and supported in such a manner as will prevent sagging. Especial care shall be taken to prevent patch concrete from drying out and to cure it thoroughly, as required in article 18 below.

18. CURING OF CONCRETE

Concrete, after taking its initial set, shall be protected from drying out at all times during the first seven days after it is deposited. If the concrete is so located as to require especial water tightness this curing period shall be increased to twenty-one days. (*Note 19*) Protection may be afforded by replenishing the supply of moisture to offset losses by evaporation or by sealing in the water carried by the concrete so that it cannot later evaporate. All portions of the structure shall be kept moist and warm simultaneously for the full curing period of seven or twenty-one days and any portion of the time during which either moisture or warmth is lacking shall not be counted as effective for curing.

19. COLD WEATHER PROTECTION

Artificial heat shall be provided and effective enclosure maintained, whenever necessary, to insure that the air in contact with concrete, for a period of seven days after placing, shall not fall below 50° F. for any considerable time. The temperature within

(*Note 20 Continued from Page 90*)

all the concrete. Where, in moderate weather, only the story below the freshly placed concrete floor is enclosed, the upper surface of the concrete must be protected with sawdust, hay or similar insulating material. Temperatures in excess of 100°F in the enclosure, tend to dry out the concrete. If salamanders with water-evaporating pans over them are used, or if live steam is used for curing, there is no danger (and in fact much gain) from using moderately high temperatures in the enclosure.

Note 21

In heating sand or gravel (or stone) on a small job by the usual method—maintaining a fire in a metal tunnel through the storage pile—considerable moisture will be driven off and the mixing water may be increased to maintain the usual warm weather consistency (best measured as slump—see note 13, page 82) for the water-cement ratio specified. Where live steam is permitted to escape in the piles, on the other hand, much water is introduced into the sand and gravel (or stone) and the measured water must be *reduced* to maintain the consistency. Heating the water alone is the cheapest way to heat concrete and introduces the fewest complications, and there is no limit to the temperature of the water, provided it is introduced into the mixer with the sand and gravel (or stone) and so cooled to 150°F or less before it meets the cement. Very hot water may cause a flash set of the cement and should not be used with hand mixing. A properly operated kerosene torch in the mixer is effective, provided sufficient time is allowed to heat the entire mass of the concrete.

Note 22

Since the strength, water-tightness and other desirable properties of concrete are dependent on a low water-cement ratio, any increase in the water content by rain or snow or ground water has the same effect as increasing the mixing water. Where concreting must be continued in bad weather, the consistency should be made as stiff as can be handled properly (with extra spading) and the extra cement added as specified. As soon as possible the fresh concrete should be covered. In many cases, it is possible to

(*Note 22 Continued Page 94*)

the enclosures shall not exceed 100° F. (*Note 20*) Moisture shall be provided within the enclosure as required by article 15.

When necessary to insure that the fresh concrete shall reach the forms at a temeprature of not less than 50° F., the materials (water only in moderately cold weather and aggregates also in very severe weather) shall be heated. The concrete may be heated in the mixer by any means that will not impair its quality, (*Note 21*) and subject to the approval of the Architect or Engineer. Dependence shall not be placed on salt or other chemicals to prevent concrete from freezing. No frozen materials or material containing lumps of snow or ice shall be used. Manure when used for protection, or moisture from manure, shall not be applied directly to, nor be permitted to come in contact with concrete.

20. Water supply

An adequate supply of water for cleaning formwork and for curing concrete shall be installed so as to be available (at all levels) before concreting starts and for at least the period of curing as required by article 15.

21. Protection of concrete work

Concrete shall be protected from washing and from the addition of excess water in the concrete during stormy weather, until such time as it has sufficiently hardened to resist washing or penetration. One extra sack of cement, per cu. yd. of concrete mixed during stormy weather, shall be added to maintain the required water-cement ratio and surface water shall be drained away from the fresh concrete during heavy rains. (*Note 22*) Additional measures shall be taken to safeguard the quality of the concrete, if necessary.

Concrete work shall be protected from injury during the removal of formwork and from injury due to the storage or movement of materials in or over the structure during construction.

22. Cement floor finish and under-finish

Cement floor finish or under-finish (cement finish shown on plans to be covered by linoleum or other surfacing material), if less than one and one-half inches thick, shall be placed as soon as the structural concrete has hardened sufficiently for workmen

(*Note 22 Continued from Page 92*)

leave the finished surface slightly low and to bring it up to grade by scattering on a mixture of dry sand and cement (in the same proportions as the sand and cement in the regular mix) to absorb the extra water. In footings it is permissable to use a dry batch of concrete for the same purpose. All methods used for this purpose must be approved by the Architect or Engineer.

Note 23

A steel trowel is a dangerous tool and may easily be (generally is) overworked. Dusting of concrete floors is commonly due to overworking with a steel trowel and to the use of fine sand. For work exposed to the weather, such as sidewalk finish, it is much better not to use the steel trowel at all. A wood float will give a sufficiently smooth and far more permanent finish. Where a trowelled finish is required the finishers must be restrained from starting until a single trowelling will leave the surface completed. Each additional trowelling damages the surface by bringing additional fine material to the top. Water should never be sprinkled on a finish to permit of easier trowelling—it is certain to result in dusting and impermanence. Floor finish should have especially good curing, as they are subject to severe wear.

Note 24

A mortar (or concrete) topping for concrete slabs, far superior to the usual product, may be secured at a very reasonable cost in spite of its novelty to the average cement finisher, by the following method. Instead of the usual mortar, use for topping a *concrete* composed of one part cement, one part coarse grained sand (not over 10 per cent passing the No. 50 sieve) and one and one-half to two parts of gravel or crushed stone retained on the No. 4 sieve and passing the $\frac{3}{8}$-in. screen. Mix this with 4.5 to 5 gal. of water per sack of cement for a period of two minutes (to give a fat, easily worked concrete). Place, screed and wood float this topping, then allow to stand for from 30 to 48 minutes, so that it becomes sufficiently stiff to prevent the fine material from being drawn to the surface by the steel trowel. Finally go over with the steel trowel, to give a dense, hard surface. With this kind of

(*Note 24 Continued Page 96*)

to walk on it, or a dry mixture of *coarse* sand (*Note 2*) and cement, in the same proportions as the mortar in the concrete, may be distributed uniformly over the surface of the concrete before initial set has occurred. In either case the method used must result in the formation of a mortar surface layer of uniform consistency (about four-inch slump) without excess water which shall be darbied to a true surface and trowelled later to a dense, smooth finish. The surface shall not be gone over more than twice with a steel trowel. For surface exposed to the weather, a wood float shall be used, entirely replacing the steel trowel. (*Note 23*)

Stair finish shall be laid in the same manner as floor finish.

Mortar for floor finish or under-finish shall be made with the same proportions of cement and sand as is used in the concrete to which the finish is to be applied. In no case shall the volume of cement exceed 40 per cent of the volume of the fine aggregate. (*Note 24*)

23. Concrete floors on ground

Concrete floors shall not be placed directly on the ground, other than sand or similar material, except for the lower course of two-course floors having a water-proofing layer between the courses. One-course concrete floors on ground, sidewalks and parking strips, shall be laid on top of a plain cinder, stone or sand filling at least five inches thick, tamped and finished accurately to the required grade of the underside of the concrete. They shall be of Class A concrete of the thickness shown on plans (but not less than five inches thick.) They shall be finished as specified in general for floors or as called for on plans.

Open joints (⅞ inch wide) shall be left between such a floor slab and the enclosing walls and columns and this joint shall later be caulked with asphalt mastic. In case the floor slab is exposed to more than 40° F. variation in temperature, or is subject to changes in moisture content, or is more than 100 feet long in any direction, similar joints shall be made at intervals of not to exceed one hundred feet and caulked in the same manner.

(Readers are referred to the Journal *for January, 1931, for discussion which may develop. Such discussion should reach the Secretary by December 1, 1930.)*

(*Note 24 Continued from Page 94*)

topping (with very little fine material in it), after it has been allowed to stiffen, the damage from steel trowelling is avoided and fine, dust-free, weather-resistant surfaces are produced.

A topping of concrete instead of the usual mortar is not required by this specification. It is *permitted* as an alternate, unless the Architect or Engineer definitely calls for it, in his typewritten specification.

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Discussion of Report of Committee 502

Construction Specifications for Concrete Work on Ordinary Buildings (502-30T)

The discussion of this specification is continued from the Journal *for March* (A. C. I. Proc., *Vol. 26, p. 580). Written by Mr. Lord, as Author-chairman of Committee 502, with the cooperation of the critic members, it was published in the* Journal *for November, 1929* (*Vol. 26, p. 1*) *and presented to the 26th annual convention. As there amended* (*See Vol. 26, p. 580*) *it was given tentative adoption. If unamended in substance it will be in order at the 1931 convention to move its submission to letter ballot as a Standard of the Institute.*—Editor

BY GEORGE A. SMITH*

I am most heartily in accord with the Institute's present plan of standardizing practices involving the use of portland cement, and feel that what is done will be for the best interest of all. With present practice in the manufacture of concrete so variable, I am impressed with the value of such a Specification as that presented by Committee 502. It surely will help greatly in unifying practice.

My attention was directed particularly to Article 10. "Admixtures and Special Cements." If paragraph one were included in a specification and then interpreted literally, such materials could have no part in the program until such a time as it would be possible to obtain all the information stipulated. Any specification should be reasonable and just.

Any material used in concrete should be studied as carefully and thoroughly as time and conditions permit. However, to

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require that materials shall be "thoroughly tested by reputable independent investigators, so as to demonstrate their effect on the strength, elastic properties, permeability and permanence of concrete produced from materials such as are being used on this work," before it may be used appears to be unnecessary in view of the Architect's and Engineer's present knowledge of admixtures and their functioning.

How many tests are made to determine the elastic properties, and permeability or the permanence of concrete made with the particular brand of cement proposed for a particular job? Because portland cement is to be used is no reason why all the properties of the concrete will be the same regardless of the brand used. Different brands of portland cement may have different properties due to different methods of manufacture, to small variations in the chemical composition or to inherent properties of the raw materials. All portland cements are acceptable for concrete work when they pass the minimum requirements of the A. S. T. M. because experience has shown that such cements have usually given satisfactory results when properly used. When this is taken into consideration why should such a question be raised about admixtures which are manufactured under definite specifications and which have given successful service in the past? Elaborate studies for determining the various properties are generally not required because of the time and expense involved in securing the data. In exceptional cases, however, most complete information may be desirable and highly important but such is not the rule especially on "Ordinary Buildings."

Progress in the art of concrete or in any other art is not attained by sitting back and waiting until some independent investigator sees fit to take up the study of some particular product. To insure progress and the introduction of new process and new products, manufacturers are continually studying and establishing definite knowledge regarding the uses of their materials. This information is of unquestioned value to industry and is generally accepted by engineers.

Among the admixtures now on the market many have unknown and unproven characteristics, and the data available are not so extensive as might be desired. There are, however, other admix-

tures which have proven their worth and which have been used successfully for a number of years.

Many prominent engineers and architects have found from their own experience and from that of others that some admixtures are effective in producing certain desirable results and go so far as to incorporate their use in their specifications. What better data are to be desired than the experience of engineers and architects? Is not such information reliable? The proposed specification at present excludes such materials and prevents their being used until such a time as elaborate and comprehensive tests are made under a multitude of conditions.

In order, therefore, that the proposed specification may be consistent in this regard with present practice I would suggest that paragraph one Article 10 be struck out and that the following paragraph be substituted:

> Materials to be added other than the usual ingredients of concrete (portland cement, fine and coarse aggregate and water) shall be proven suitable to the satisfaction of the Architect or Engineer. Approval for the use of such additional materials shall be in writing.

Aside from the question of approval or disapproval of admixtures, I am impressed by the incompatability of the proposed specification with the ability, and the rights and prerogatives of the Architect or Engineer. In Article 9 "Constant Source of Supply," we find "having determined upon the source and kind of cement and aggregate to the satisfaction of the Architect or Engineer, etc." Here, from data available, be it from experience or from test, he is allowed to exercise his ability and his judgment in selecting what materials shall be used. Yet, when considering other possible ingredients, we find that the specification is dictating to the responsible head what he shall do and how he shall do it. Is the specification written to govern the Architect and the Engineer or is it to govern the job and the Contractor? If it is the intent, to regulate and control the acts and decisions of the Engineer or Architect, there can be little exception to the specification. However, I do feel that such is not the meaning.

Responsible architects and engineers are capable of judging what materials shall be used and would, in all probability, incorporate as a part of their specification the above proposed amendment. To add the last part of paragraph 1 Article 10 stipulating

what the Engineer or Architect may consider would be a reflection on his ability. As now proposed we have the approval in writing and then some one comes along and dictates "and then only such materials shall be added, etc." Why not let the matter rest upon "to the satisfaction of the Architect or Engineer"?

BY G. W. HUTCHINSON*

Among other details of the material specifications, the manner of presentation of paragraph 10 "Admixtures and Special Cements" is open to question, especially when the first impression is reinforced by the tone of the author's criticism.

In a specification, drawn for national use, the amount of consideration accorded it depends not only upon its practicability, but also upon its interpretation as regards prejudice and commercialism.

It occurs to me that this paragraph should either be eliminated or relieved of the impression it will convey as now worded.

There are admixtures and special cements of several classes. Without doubt, some are not suited for all purposes, and possibly some are unsuited for any purpose. On the other hand, a prejudice is set up against those that have been used with beneficial effect.

It is felt that it is a matter of competition among producers to show the superiority of their product, etc., rather than to give them all a technical "black eye."

Due to the activity of both the proponents and opponents of admixtures, the subject has become prominent during the past few years. Upon analysis, the majority of discussion has been confined to the producers of admixtures and producers of portland cements. The controversy has reached a ridiculous stage in some instances, and reflected no credit to either side. Further, technical magazines and societies have published the "pros and cons" without censorship.

Engineers and architects, who are the judges of admixtures on their individual projects, will be handicapped by the adoption of a specification of this nature. It is assumed that the general

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specification will be promoted, in one way or another, into the building codes of the various cities. Under these circumstances, the architect or engineer for private work, regardless of his desires, finds himself unable to specify an admixture, as his specifications must conform to local building code requirements. Paragraph 10, in question, requires more information about admixtures than we know about the cement and aggregates which appear to be accepted without question.

Without going further than to discuss this paragraph generally, it would appear to the writer that an amendment should be made to remove the present reference and substitute one along the following lines.

Admixtures and Special Cements, unless specified, shall be used only upon approval of the Architect or Engineer in writing. The producer of any admixture or special cement shall have available, not only complete information regarding his product, but shall also have sufficient test data, from various acceptable sources, to indicate a consistent agreement between them with regard to the effect of the product upon the desired qualities of concrete.

It is well recognized that many of the tests regarding certain admixtures cannot be duplicated at will, and are the result of either poor testing routine, or are "freak" results so often encountered. For this reason, a reasonable agreement between laboratories would be desirable to give the user protection against the exploitation of favorable tests and the discarding of those of unfavorable nature. It would relieve the "salesman" objection, a point well taken by the author in his own criticism.

As stated before, it is desired to relieve this point rather than to attempt to discuss details in connection with the whole specification at this time. It is to the best interests of the Institute to further the use of a specification agreeable to all and at the same time protect the user and secure the most economical concrete.

The paragraph regarding admixtures and special cements is undoubtedly objectionable to a large number, and, on account of the relations between the architect or engineer and the local building inspection departments, is a serious handicap.

Unless the whole specification is considered seriously; accepted in a national sense, and not subjected to criticism during its promotion, it will reflect against rather than to the credit of the Institute.

BY C. E. ELLSWORTH*

Due to the public's confident acceptance of the Institute's work, the Institute has a most serious responsibility to the public.

If Article 10 of the "Construction Specification for Concrete Work on Ordinary Buildings" is permitted to stand, it will virtually exclude all admixtures from concrete made under this Specification.

Will it best serve the public interest to exclude *all* admixtures from concrete manufactured under this Specification?

Of late years engineers have appreciated more and more the fact that impermeability is of even more importance than strength and rigidity, in its effect on the permanence of concrete structures. In fact, never in the history of concrete construction has there been a time when the subject of water-tightness received as much thought and attention as it does at present. And the problem is not confined to such structures as dams, reservoirs, aqueducts, water-treating tanks and basins, where loss of water through percolation is involved, but includes roads, culverts, bridges, piers and abutments, retaining walls and revetments, tunnels, sewers, footings and foundations, basement and building walls, etc., as well.

Concrete surfaces exposed to the weather have a tendency to check and craze; this weathering action being due to alternate and unequal expansion and contraction of the surface concrete, under the influence of varying temperature and moisture content. Water enters the fine cracks thus formed; and in cold weather freezes, enlarges the cracks and causes incipient disintegration of the surface concrete. This cracking and disintegration progresses deeper and deeper into the concrete, permitting corrosion of the steel reinforcement, and reducing the effective sectional area of both steel and concrete.

Underground concrete surfaces are often exposed to acid and alkaline ground waters which are highly corrosive in their action. These waters are absorbed by the surface pores and are thus brought into close contact with a tremendous area of concrete surface; and, due to the large area affected, dissolution of chemical

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constituents of the cementing material takes place at a proportionate rate, resulting in a porous or cellular concrete structure. The reinforcing steel is also attacked and corroded; and, in the course of time, the underground, concrete structure becomes unfit for service, and expensive repairs or replacement becomes necessary.

It is evident that if concrete structures are to prove permanent and safe, they must be water-tight; and *the condition of many concrete structures today is conclusive evidence that plain concrete alone is not in itself sufficiently water-tight.* Thus the importance of an effective means for waterproofing concrete becomes obvious.

The writer's statements so far as fully confirmed by F. R. McMillan and Inge Lyse of the Portland Cement Association in the Introduction to their paper "Some Permeability Studies of Concrete:"[1] The paper referred to possesses unusual merit; and the co-authors deserve much commendation and respect for the accuracy and frankness which marks their work. The most significant conclusion reached by these two investigators is expressed by them as follows: "The tests have demonstrated what has been observed in concrete structures that defects in placing are a much more important factor in the leakage than ordinary differences in mixtures, materials, or water content." This statement is really an unqualified endorsement of a proper admixture; for it cannot be disputed that such an admixture improves the workability of concrete, and that improved workability operates to prevent defects in placing.

Granting that concrete must be quite workable when placed, if it is to prove sufficiently waterproof for permanence and safety, is then a proper admixture to be preferred to added cement as a means to obtain the required degree of workability? There are several good and sufficient reasons why such an admixture—hydrated lime for instance, is to be preferred:

(1) Lime putty is much more viscous, sticky and slippery than cement paste; hence not only is a lesser volume of the former required for a definite degree of workability, but also volume for volume lime costs only one-half as much as cement. The viscous, sticky lime putty is also more efficient in preventing the separation

[1]JOURNAL, A. C. I., December, 1929 (*A. C. I. Proc.*, Vol. 26, p. 101).

(unmixing) and segregation of the component materials of the concrete; thus guarding against the defects in placing which is the most important factor influencing leakage in the finished concrete. The slippery lime putty acts also as a lubricant coating the particles of the cement and aggregates, and makes them smooth and mobile and easy to chute and otherwise handle into the forms and around and between the reinforcing steel; thus the cost of handling and placing the concrete is reduced and, furthermore, exposed concrete surfaces require no patching or finishing.

(2) The extremely minute lime particles, as compared with cement particles, is another reason for increased impermeability where lime is used; for these minute particles of lime act to fill the void spaces between the cement particles as well as the sand particles, leaving only the most infinitesimal void spaces between the lime particles themselves for the possible passage of water. In addition, these extremely minute lime particles when saturated with water become colloidal or gelatinous (glue-like) in nature, and not only make the lime putty viscous and sticky but also act to seal the infinitesimal void spaces left between the lime particles themselves. The presence of these minute lime particles in the void spaces between the sand and cement particles also makes a stiffer and denser matrix which holds the coarse aggregate in suspension during transportation of the concrete from mixer to forms.

(3) Added cement means a richer concrete mix; and the richer the mix the greater the volume changes in the concrete due to variations in temperature and in moisture content. It has already been pointed out in this discussion, that volume change is responsible for cracking and disintegration of surface concrete; hence lime is to be preferred to added cement, much less lime being required and, also, a mixture of lime and cement being less sensible to temperature and moisture changes than straight cement.

(4) An admixture of lime increases both the strength and the toughness of all but the richest concrete mixes, while added cement increases the strength only.

Hydrated lime is probably the most efficient integral water-tightening medium available today for concrete. Test data accumulated over a period of more than 30 years support this con-

clusion. Portland cement was invented in 1825, but, prior to 1900, very little was used in the United States; hence it can be said that lime has been successfully used as an admixture in concrete from the time portland cement concrete was first recognized in this country. Results of authoritative and unbiased tests made during the 30 year period referred to above, and representing competent evidence of the value of lime as an admixture in concrete, follow:

It seems obvious that the exclusion of reputable and time-tested admixtures from any concrete specification will not serve best the interest of the American public and, that being the case, Paragraph 10 of the "Construction Specification for Concrete Work on Ordinary Buildings" should be amended at once to not only permit but even recommend the use of a reputable and time-tested admixture.

DATA

Tests by Sanford E. Thompson

The textbook "Concrete, Plain and Reinforced," by Taylor and Thompson, is well known to concrete engineers. Sanford E. Thompson, co-author of this book, was one of the earliest advocates of lime in concrete, and used it extensively in his own work. As early as 1903, he made a few permeability tests with hydrated lime as an admixture, and found it a valuable material for water-proofing. In 1906, he made another test which he reports as follows:

TEST FOR: Permeability.
CONCRETE MIX: 1:2:4.
CONCRETE THICKNESS: 4 inches.
WATER PRESSURE: 80 pounds per square inch.

*Hydrated Lime Per Cent	Flow of Water, Grams per Minute		
	14 Days	21 Days	28 Days
0	5.52	2.92	1.91
2	9.20	2.55	1.63
4	2.82	1.49	0.76

*In terms of weight of cement.

From these test data, Mr. Thompson decided that 5 per cent hydrated lime was the proper amount to use; such figures being outside the range of the test, but the minimum possible figure indicated thereby.

Later tests by Mr. Thompson lead him to the following conclusions, presented in a paper before the A. S. T. M. in June, 1908:

(1) Hydrated lime increases the water-tightness of concrete.
(2) Effective proportions of hydrated lime for water-tight concrete are as follows:
For one part Portland cement, two parts sand, four parts stone, add 8 per cent hydrated lime.
For one part Portland cement, 2½ parts sand, 4½ parts stone, add 12 per cent hydrated lime.
For one part portland cement, 3 parts sand, 5 parts stone, add 16 per cent hydrated lime.
Tnese percentages are based on the weight of the dry hydrated lime to the weight of the dry portland cement.
(3) The cost of large waterproof concrete structures frequently may be reduced by employing leaner proportions of concrete with hydrated lime admixture, and small structures such as tanks, may be made water-tight.

These conclusions are based in part at least on the following:

TEST FOR: Permeability.
CONCRETE MIX: See Table.
WATER PRESSURE: 60 pounds per square inch.

*Lime Per Cent	Concrete Age Days	Test Period Hours	Flow of Water Grams per Hour
1:2:4 Concrete:			
1	40	4¼	74.8
4	41	5	28.4
7	42	6¼	5.2
10	46	18	1.6
1:2½:4½ Concrete:			
0	45	6	32.5
10	49	11	0
14	50	27	0
1:3:5 Concrete:			
0	50	14	70.6
8	51	17	3.6
14	50	13	0.7
20	53	15	0.7

*In terms of weignt of cement.

Tests by Prof. M. O. Withey

Permeability and strength test, with lime as an admixture, were conducted at the University of Wisconsin in 1920 under the direction of Prof. M. O. Withey. Two different concrete mixes were tested and the following conclusions were drawn from the results of the tests:

(1) Hydrated lime, when added to the cement increased the compressive strength of the concrete which had a slump of 4 inches, about 4 per cent for each per cent of lime added. For the concrete which had a slump of 9 inches, the strength was increased about 6½ per cent for each per cent of lime added.

(2) The 1:2.8:6.5 mix by volume was very pervious. The addition of 4 per cent of hydrated lime increased the imperviousness of the mix very materially. The addition of 8 per cent of hydrated lime produced practically the same effect as the addition of 4 per cent.

The test data for the richer mix show conclusively that the addition of a proper amount of hydrated lime improves both the strength and the watertightness of even the richer concrete mixes; hence such test data are included herewith.

TEST FOR: Permeability and Strength.
CONCRETE MIX: 1:2.1:4.9.
WATER PRESSURES: 40 pounds per square inch.

*Lime Per Cent	†Water Per Cent	Unit Strength	Flow of Water, Gallons per Hour 0-50 Hrs.	20-50 Hrs.	40-50 Hrs.
0	6.66	2,030	.00023	.00015	.00011
2	6.83	2,235	.00017	.00009	.00006
4	6.80	2,678	.00019	.00012	.00011
6	6.73	2,855	.00017	.00011	.00010
8	6.86	2,470	.00015	.00007	.00007
10	6.87	3,035	.00017	.00012	.00012
0	7.40	1,266	.00030	.00021	.00018
2	7.37	1,884	.00036	.00023	.00023
4	7.30	1,585	.00026	.00016	.00017
6	7.40	1,664	.00022	.00013	.00012
8	7.40	1,893	.00022	.00012	.00010
10	7.43	2,225	.00025	.00016	.00013

*In terms of weight of cement.
†In terms of total weight of dry materials.

Further tests under the direction of Professor M. O. Withey at the University of Wisconsin were conducted in 1921; and the following conclusions were drawn from the results of this check series:

(1) The rate of flow of water into specimens was, in general, decreased by the addition of hydrated lime to the mix. The decrease was also generally greater for 10 per cent of lime than for 5 per cent.

(2) For the gravel concrete series of 4-inch slump the results do not indicate a great advantage in the use of hydrated lime. The set with 5 per cent of lime was somewhat more impervious than the plain concrete, and the set with 10 per cent of lime showed about the same flow as the concrete with no lime.

(3) The series of gravel concretes with a 9-inch slump shows that the addition of 5 per cent of lime slightly decreased the flow of water, and that 10 per cent of lime decreased it to less than half of the flow for plain concrete. As before, the results are variable for the plain concrete slightly more uniform for 5 per cent of lime, and quite uniform for 10 per cent lime. . . . Again the uniform results and decreased rate of flow indicate that hydrated lime increased the water-tightness of the concrete.

(4) The limestone series of specimens gives average results which indicate that the addition of 5 per cent of lime decreased the rate of flow to about one-tenth of the rate for plain concrete, and 10 per cent of lime causes some additional reduction:

(5) These results again show that hydrated lime decreased the permeability of concrete, but do not give any indication of the relative effect of the addition of 5 per cent and 10 per cent of lime. The great gain in water-tightness when 5 per cent of lime is added can be attributed mainly to gain in workability, and partly to the effect of the lime in filling the voids in the mix. . . . The first 5 per cent of lime made the mix workable, and dense cores were obtained. The addition of the next 5 per cent of lime could not be expected, in the case of this aggregate, to cause a corresponding gain in water-tightness.

The test data on the limestone concrete for the intervals 0-100 hours, 20-100 hours and 40-100 hours follow. The rapid leakage in the case of the plain concrete is due to separation and segregation of the component materials.

TEST FOR: Permeability and Strength.
CONCRETE MIX: 1:2.45:6.2.
WATER PRESSURE: 40 pounds per square inch.

*Lime Per Cent	†Water Per Cent	Unit Strength	Rate of Flow, Gallons per Hour 0-100 Hrs.	20-100 Hrs.	40-100 Hrs.
0	6.47	1,580	All specimens leaked rapidly		
5	6.58	1,828	.00201	.00176	.00179
10	6.65	1,912	.00153	.00134	.00234

*In terms of weight of cement.
†In terms of total weight of dry materials.

Tests by Prof. H. C. Berry

Strength tests with hydrated lime as an admixture were conducted at the University of Pennsylvania in 1921 under the direction of Prof. H. C. Berry. Two different concrete mixes were included in the tests, and each mix tested at a wet and at a dry consistency corresponding to a flow of 190 and 165 respectively on the U. S. Bureau of Standards Flow Table. The data follow:

TEST FOR: Strength.
CONCRETE MIX: 1:2:4

*Lime Per Cent	†Per Cent Water Dry Mix	Wet Mix	Compressive Strength Dry Mix	Wet Mix
¾-inch Crushed Stone Aggregate:				
0	8.7	9.4	2,842	2,049
5	8.9	10.0	2,889	2,842
10	9.5	10.0	3,021	2,540
¾-inch Gravel Aggregate:				
0	7.8	8.9	2,673	2,016
5	8.5	8.9	2,338	2,338
10	8.9	9.3	2,340	2,340

*In terms of weight of cement.
†In terms of total weight of dry material exclusive of lime.

TEST FOR: Strength.
CONCRETE MIX: 1:2½:5.

*Lime Per Cent	†Per Cent Water Dry Mix	Wet Mix	Compressive Strength Dry Mix	Wet Mix
¾-inch Crushed Stone Aggregate:				
0	7.6	8.1	1,842	1,505
5	8.25	8.6	2,116	2,248
10	8.6	9.1	2,022	2,384
¾-inch Gravel Aggregate:				
0	7.5	8.3	1,957	1,631
5	8.3	8.35	1,865	1,716
10	8.2	8.3	1,822	1,914

*In terms of weight of cement.
†In terms of total weight of dry material exclusive of lime.

It should be noted that the "Dry Mix" concrete is much too dry for practical use in the field, and that the addition of lime increased the strength in every case for the "Wet Mix" i. e., a practical field mix. Thus, these results are in entire accord with the findings of Prof. M. O. Withey and Sanford E. Thompson. Many other tests can be cited, the results of which are in substantial agreement with those quoted; however, this discussion of lime as an admixture in concrete will close with the following report on Wacker Drive, a two-level street in the new Chicago Boulevard system.

Concrete in Wacker Drive is designed to withstand the severe exposure to the elements imposed by its location. Hence the specifications required an admixture of 8 pounds of hydrated lime per sack of cement in all exposed concrete. T. A. Evans, Engineer of Design, Bureau of Design, Chicago Board of Local Improvements, is the authority for the following tabulated figures and pertinent comments under date of September 25, 1925.

EFFECT OF HYDRATED LIME ON †WORKABILITY OF CONCRETE MIXTURES

*Lime Per Cent	Concrete Mix 1:1½:3	1:2:4	1:2½:5	1:3:6
0	44	108	169	242
5	33	103	167	202
10	31	81	125	185
15			129	171

*In terms of weight of cement.
†The lower the workability figure the more workable the concrete.

We have poured a portion of the viaduct structure without the use of hydrated lime and have found that the work of handling and tamping around the heavily reinforced portion of the concrete structure was greatly facilitated on the sections on which we have added lime to the mixture, so we are now using lime on the balance of the work.

A more comprehensive report by R. W. Priest, Field Testing Engineer, follows:

Hydrated Lime in Wacker Drive Concrete—(Synopsis)

A certain degree of skepticism is often expressed by engineers and contractors as to the real advantage to be gained by the use of an admixture in concrete. Questions as to the relative strength-deterioration, absorption, permeability, density and workability of concrete with and without an admixture often arise. As Field Testing Engineer for the City of Chicago on the Wacker Drive, the writer has had exceptional opportunity to study this question. The facts obtained by test on this job are believed to be conclusive.

Hydrated lime was used as an admixture in approximately 60 per cent of the 120,000 cubic yards of concrete in this project, the exception being that lime was not used in the concrete placed below ground, such as caissons, sub-girders and pavement foundations.

The concrete on this work was a nominal 1:2.33:3.67 mixture (1:6 specifications). The fineness modulus of the coarse aggregate and the sand were respectively 6.84 and 2.85. The total water allowance was 7 gallons per sack of cement and each batch of concrete was mixed 1½ minutes in a rotary batch mixer. From all concrete poured, 6-inch by 12-inch field cylinders were made at regular intervals and cured under three conditions so that the results express actual conditions in the concrete as placed.

These field specimens were tested for compressive strength at various ages up to one year and additional specimens were tested for absorption and permeability. The results of these tests are now available and it is possible to make a conclusive comparison between the concrete without admixture and concrete containing 8 pounds of hydrated lime per sack of cement.

A careful study has been made of the compressive strength of about 1,000 representative cylinders taken over a period of two years. These thousand cylinders are only about one-sixth of those taken on the job, but they represent identical mixtures and identical conditions, of curing and testing, which are necessary for a fair and conclusive comparison.

Number of Cylinders	Age at Test	Compressive Strength Average per Square Inch
Concrete without lime (1:6 Mix):		
250	7 days	1,632 lbs.
250	28 days	3,176 lbs.
10	1 year	4,362 lbs.
Concrete with 8 per cent lime (1:6 Mix):		
250	7 days	1,720 lbs.
250	28 days	3,214 lbs.
10	1 year	4,630 lbs.

Considering the large number of the tests made under identical conditions, it is conclusive that the addition of lime does not lessen the strength of concrete and, without reducing the water content as is possible with lime, the strength was slightly increased at all ages tested.

In a test to determine the effect of the addition of lime on the absorption of concrete, it was found that these cylinders containing the admixture absorbed an average of 3.23 per cent of water by weight during an immersion of 96 hours. The specimens without the lime gave an average absorption of 4.126 per cent with the same time of immersion.

The investigation also included penetration tests which were on disc specimens 8 inches in diameter and 2 inches thick, 28 days old at the time of test. Ten square inches of the face of these discs were subjected to a water pressure of 22 pounds per square inch for a period of 72 hours. The discs containing no admixture permitted the passage of 15 per cent more water than those containing hydrated lime.

In order to settle, to our own satisfaction, the question of the yield of concrete when an admixture is used, a series of tests were conducted which demonstrated that the use of 8 per cent of lime did not give an increase, but rather resulted in a slightly less volume of concrete than when it was omitted. The writer believes that this work proves that concrete containing lime is more dense than without it.

In conclusion it was observed on the work at Wacker Drive that concrete containing lime was more plastic and workable, and was more easily handled with less chance of segregation of aggregates. To a contractor these features are money savers.

From the Engineers' standpoint it was observed that with lime, less water was needed to make a workable mixture. The tests showed increased strength, decreased absorption and decreased penetration; all of which follow logically the demonstrated greater density of lime concrete.—R. W. Priest, Field Testing Engineer, Wacker Drive; Board of Local Improvments; Bureau of Design, Chicago.

AUTHOR'S CLOSURE*

Mr. Brown's discussion† was not received by me prior to the convention and was not discussed there. I am aware of the apparent hardship that disheartens him. But I still think that the Contractor, as the most experienced person connected with the detailed operations of construction work, should continue to provide "all usual necessary and essential portions" of the work even though not shown or specified completely. If he is in doubt in making up his estimate—the only complete list of every item required—as to whether lintels are stone, terra cotta or concrete, he should find out. On the ordinary building that is not a difficult thing to do and the Contractor is in far better

*By Arthur R. Lord, Lord & Holinger, Chicago.
†H. M. Brown, Journal, March 1930. (*A. C. I. Proc.* Vol. 26, p. 580).

position than any one else to do this necessary safeguarding work.

The second paragraph in Article 11 deals with "gaps" in the reinforcement—small unreinforced areas such as may occur on any job either by oversight of the detailer or by careless steel placing. It has nothing to do with the spacing of bars in the regular bands or systems, but is concerned only with "gaps" where the regular systematic groupings of bars leave an unreinforced opening. If this opening were large, or if there were many of them, I assume that the Contractor would call in the Engineer to complete his design and that he would be paid for any considerable amount of additional steel required. But for the small unreinforced triangle or space indicated by the word "gap," no such elaborate or time consuming action is desirable—simply put in $\frac{3}{8}$ in. at 6 in. o. c. and pass on. This is the simplest and easiest way to cover such minor openings and the amount of steel consumed is negligible in my experience. This provision was added by a highly experienced critic.

Placing concrete under water is quite common in buildings involving cylindrical piers or "caissons" of concrete, which is a common type of foundation in our larger cities today. I have never seen bottom dump buckets used in such work but this device was nevertheless inserted in the specification before its adoption as a tentative standard by the Institute. So anyone may use this method who wishes to when operating under this specification.

One function of a specification of this sort is to protect owners from "extras" in cases where a reasonable contact of the bidder with the Architect or Engineer would eliminate uncertainties. I assume, and the lack of any considerable amount of unfavorable criticism of this specification appears to support the assumption, that Contractors want to stay on good terms with their clients and wish to cover in their bids all required work in their line, rather than to catch the Owner unawares with extra charges for a lot of petty items. These specifications follow the time-honored method of accomplishing this end—it makes the contractor financially interested in eliminating uncertainties before entering into contract.

Whenever it has seemed possible and proper I have, with the consent of the critic members of the committee, made the appropriate changes in the wording of this specification, as suggested by the discussion received. Many changes were submitted to the convention in 1930 and incorporated in the specification as tentatively adopted by the Institute. The recent discussion, received since the convention, has centered around article 10. With no thought of malice, I submit that the authors of this discussion have not read this article. Doubtless they meant to read it, but their discussion reveals that they did not read it soberly and with the wish to understand. It does not seem to me to be obscure. Article 10 does not prohibit the use of admixtures. On the contrary, it specifically provides for the use of such admixtures as come with a satisfactory record of use, or even those that can win the approval of the architect or engineer—a none too difficult feat surely. It does, by its negative form of statement, act to restrain the contractor from rushing into the arms of the first plausible admixture salesperson that he chances to meet.

There are today upward of 250 materials, or rather packaged products, the producers of which would like to have incorporated in concrete. It is a natural wish. So much concrete is used that even a small amount in every yard of concrete would make a nice business total. Some of these "admixtures" have been extensively used, others hardly used at all. Some of them are doubtless desirable additions to concrete for certain uses, common uses, as workability agents or waterproofers. Some of them are pure gambles. Article 10 requires evidence that admixtures used on work done under Specification 502 have a history as well as a sales agent. It is designed to protect the manufacturer of a worth-while admixture from unworthy competition. Evidently lime, one of the longest-used of this general class of material, does not wish protection. But the owner is entitled to protection in his specification, even if the manufacturer scorns it. I believe that Article 10 should stand, both for admixtures (including waterproofing compounds) and for the new special cements.

Mr. Ellsworth's leading witness in favor of lime is a job on which I personally approved its use, for the conditions holding on

that job. I rejected in the neighborhood of fifty other admixtures that were pushed for use on the same job, most of them depending chiefly on political backing rather than on the kind of evidence required by Article 10. If Mr. Ellsworth and Mr. Hutchinson will cool off long enough to read Article 10 quietly, I believe that they will agree that it is a common sense provision in a field where there are so many products of so diverse merits. It seems to me also that they might agree that even lime isn't the best admixture to use for all concrete, and that some concrete does not require any help from admixtures. Lime isn't altogether indicated for the concrete of a dam intended to impound lime-thirsty mountain water. Article 10 puts the decision on the architect or engineer where it properly rests. If this article results in worth-while materials being advanced on their scientific merits and proven results, instead of on the fallacious theory that concrete is a fair dumping ground for any material that does not stop the mixer, it will be worth a few misunderstandings such as these, much as I regret them.

Discussion of the Report of Committee 802

"Good Practice in Concrete Floor Finish"*

BY ROBERT SETH LINDSTROM†

The writer wishes to submit further discussion, so that when and if a specification is formally prepared and submitted to the Institute for adoption, all of the kinks will have been ironed out and a floor finish specification presented that will be accepted by the architect-engineer and building construction industry for universal use.

Portland cement is the tie that binds the ingredients entering into portland cement concrete, solidifying the structural mass to a point where concrete has been generally accepted in reinforced concrete construction. In wearing surfaces of portland cement concrete subjected to traffic as in floors, ramps, and stairs, there must also be a compact, homogeneous finish.

To obtain the densest possible concrete for floor finish the mix, sizes, shape, and quality of the aggregates must be considered more carefully than aggregates for structural concrete due to the experience that if the aggregate is not properly and uniformly graded from coarse to fine, voids will occur and the density of the floor topping be impaired.

Nothing has done more harm in lessening the use of concrete floors than the method called "Dusted-on Finish."

In a dusted-on finish all the rules and regulations of good practice are violated and the water-cement ratio lost sight of.

We have all learned by our field experiences that the proper amounts of water, cement and graded aggregate must have such a period in a mixer as will thoroughly mix water, cement and sand so that when leaving the mixer the mass will not segregate in handling or placing. Additional cement, sand or other ingredients thrown or dusted on in a dry state cannot cover the

*Journal, A. C. I., March, 1930; *A. C. I. Proc.*, Vol. 26, p. 520.
†General Manager, Advance Waterproof Cement Co., Chicago, Ill.

surface uniformly nor will there be sufficient water properly to take up the cement for a uniform, plastic condition like the material that has passed through the mixer.

Since standard portland cement must pass a certain percentage through a 200 mesh sieve it is necessary to use a fine aggregate grading, beginning nearer the fineness of the cement and gradually increasing the size to an ideal sand grading, meeting with Fuller's formula for ideal sand grading. This formula produces a grading as follows:

4	Mesh to the inch passing	100%
8	" " " " "	75%
14	" " " " "	50%
28	" " " " "	25%
48	" " " " "	15%
100	" " " " "	0

Such fine-to-coarse aggregate with portland cement and water, machine mixed for fully two minutes, properly laid and troweled will give a 100% non-dusting portland cement floor topping and any excess of cement and sand dusted on will change the entire mix and create a dusty, non-uniform mixture that will add to the cost of the work.

Field practice and years of tests have shown conclusively that the old 1:2 mix, taking into consideration amount of water and portland cement, together with size and grading of aggregate, should be standardized and offered to the committee that will formally and finally draft floor finish specifications.

ABSTRACTS

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of the current literature of cement and concrete

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COMMITTEE ON ABSTRACTS

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MATERIALS

ADMIXTURES

Bentonite and its use in the industry. *Le Genie Civil* (France), Oct., 1929; reviewed in *L'Industrie Chimique* (France), June, 1930, V. 17, No. 197, p. 407.—Bentonite is colloidal clay, which is found in large deposits in the United States and Canada.* When brought in suspension in water, part of its constituents hydrolyze. It can be used for following purposes: as detersive agent, as stabilizer for oil emulsions, as water softener, especially for permanent hardness, and as concrete admixture. Bentonite forms with great number of oils stable emulsions.—A. E. BEITLICH. (*According to U. S. Bur. of Mines Tech. Paper 438, 1928, Bentonite occurs in quantity in Wyo., Nev., Calif., S. D., Id., N. M., small deposits probably a dozen other states; little or none in states east of Mississippi.—EDITOR)

AGGREGATES

Behavior at high temperatures of concrete containing blast furnace slag. RICHARD GRUN AND HUGO BECKMANN. *Archiv fuer das Eisenhuettenwesen* (Germany), May, 1930, V. 3, No. 11, p. 677-83.—The statement confirms itself that quartzous aggregates are less suitable for concrete which is exposed to high temperatures. It was found that concrete made with blast furnace slag shows least decrease in strength under heat treatment. Slag may be mixed with cement or used as aggregate in concrete. It seems that the best concrete for high fire resistance can be made from dense, strong slag as aggregate by use of the voids-curve or Fuller curve and by use of cement containing blast furnace slag.—A. E. BEITLICH

Corrosion of steel by breeze and clinker concretes. *Dept. Sci. Ind. Res., Special Report* No. 15, (England).—Instances have been reported of serious corrosion of steel in contact with breeze and clinker concretes, which are much used because of low density and cheapness. Tests undertaken to investigate these effects included an examination of behaviour of solutions derived from action of moisture on various types of coal residue aggregates. Since it has been found that corrosion may be rapid even under dry indoor conditions, examination was made of the corrosive power in moist air but out of contact with the sources of liquid moisture. Also tests were made to ascertain relation between permeability and corrosive power, and the effect of replacing fines in breezes and clinker aggregates by sand. It is considered that sulphur content of the materials is prime cause of corrosion and that porosity and permeability are of minor significance in this connection. Accounts are given of the various tests, and the particular properties of coal residue aggregates responsible for corrosion with their relative importance are indicated.—JOHN E. ADAMS

New Pycnometer measures free moisture in aggregates. D. D. MCGUIRE and W. H. ROWAN. *Concrete*, May, 1930, V. 36, No. 5, p. 41.—Change in Tennessee highway department specifications for control of proportions of fine and coarse aggregate by weight made it evident that one of major factors of this type of control was accurate knowledge of correct per cent of free moisture in aggregates and their apparent specific gravity. New type pycnometer was developed from several revamped pieces of equipment for this purpose. Container, is made of non-corrosive, metallic material, such that its base is 10 in. in diameter and top 3 in. in diameter. Height is 12 in. Under bottom are placed three round points of contact with weighing table of a solution balance. To determine apparent specific gravity, it is only necessary to determine weight of can and bar, water which can will contain to point where moisture gauge bar touches its surface, and weight of sample under

consideration. To determine free moisture, apparent specific gravity, G_s, in saturated and surface-dried condition, and apparent specific gravity, G_w, in a wet or stock-pile condition, are required. From formula, $\frac{G_s - G_w}{G_s \times (G_w - 1)} \times 100 = M$, the per cent moisture may be readily obtained.—C. BACHMANN

Use and abuse of building materials. A. M. GILES, *Builder* (England), June 6, 1930, and June 13, 1930, V. 138, No. 4557, and No. 4558, p. 1099 and 1149.—Concrete: The historical development of the use of concrete is outlined and reference made to the greater lasting quality of concrete as compared with stone. For aggregate any hard substance may be used, although cinders are not recommended owing to corroding effect on the steel. It is recommended that sand be screened from gravel and remixed to ensure proper proportions. Limestone is liable to decomposition under great heat and is not suitable for fireproof work. Essential quality of all aggregates is cleanness and freedom from earthy matter. This should be tested by allowing sample to stand in water for a time. Dirt will collect on the top of the aggregate as a film. A sample may also be tested by shaking up with weak solution of caustic soda and allowed to stand for 24 hours. If solution above aggregate is brownish yellow too much impurity is present. Broken brick should always be well cleaned and soaked in water before mixing. In parts where washed aggregates are not obtainable, it is often advisable to fit up washing and screening apparatus combined, on site. For non-porous concrete coarse aggregate should pass a ¾ in. ring and be retained on a ⅛ in. mesh. Aggregates: For dense concrete voids must be filled; sand as well as shingle should be well graded. Too much dust in aggregates causes weak concrete since more water is required for mixing. Scientific proportioning and right consistency should be aimed at. Too dry mixes, though strong, are porous, while wet concrete takes long to set and is weaker. Methods of arriving at proper proportioning are outlined, and reference is made to the fineness modulus method of proportioning by analysis.—JOHN E. ADAMS

CEMENT

Determination of the specific gravity of cement. KARL E. DORSCH. *Tonind. Ztg.* (Germany), May 8, 1930, V. 54, No. 37, p. 627-8.—For rapid but accurate determination of specific gravity of cement a large mouth pycnometer with a long graduated, ground-in tube ending in a small funnel is used. One hundred g. cement is introduced into pycnometer which is stoppered and shaken thoroughly. Then more C_6H_6 is introduced from a burette to give an accurate measure of volume after temp. adjustment is made.—F. O. ANDEREGG

Cement. *Contr. Jour.*, June 25, 1930, V. 102, No. 2663, p. 2058.—Presence of coal in breeze aggregates may cause failure in cement renderings on concrete made with them, as well as in the concrete itself. The effect of an excess of sulphides in basic slag aggregates is not marked in dense and impermeable concrete, though its effect is very evident in plain and reinforced concrete. Calcium sulphate combines with calcium aluminate in the cement and forms calcium sulpho-aluminate, and causes disintegration. Swelling and cracking in cement rendering on brick work may be caused by sulphuric anhydride in the bricks. Concrete roads have been known to fail in same way through absorption of this compound from road sub-base composed of stone and slag. Ground waters near coal deposits, tanning liquors, fatty acids, creosote and sugar tend to disintegrate concrete exposed to their action. Whin chips and whin dust result frequently in failure to harden—due perhaps to excessive water required to wet the dust in mixing. River gravel, when coated with algae may not bond well with cement.—JOHN E. ADAMS

Lehigh Valley cement plant operates on America's pioneer mill site. *Pit and Quarry*, May 7, 1930, V. 20, No. 3, p. 36-37, 33 ill.—Explains David O. Saylor's portland cement project in 1866, his patent in 1871, and the use of his product more than 50 yrs. ago in constructing the Eads jetties at mouth of Mississippi River. Coplay Portland Cement Co. is direct successor, occupies original site, and quarries from same deposit. At this plant can be found the old fashioned, dome-type lime kiln, high vertical kiln, and improved rotary kiln. Originally rock and clinker were ground with buhr stones. This is the first cement plant to be electrically operated. Limestone deposit is about 6 mi. north of Allentown, near Coplay, Pa. It produces almost pure calcium carbonate and an argillaceous stone, each kind running uniform in color and quality. Quarry has been worked 25 yr. The face is 180 ft. high and the floor has an area of about 7 acres. Lower levels are being started. On a jig-back cars of stone are hauled up 400-ft. incline, one at a time, by an electric hoist. Primary gyratory crusher reduces the stone to 3-in. This stone is hauled in trains of 12 cars to main plant by a 16-ton gasoline locomotive. Cars are dumped by hand over a rectangular concrete 2,000-ton bin. Following 54-in. by 24-in. roll crusher, flow sheet includes magnetic separators, pulverized-coal-fired rotary dryers, automatic proportioning scales, a hammer mill, 18 fine-grinding mills, storage and blending tanks, 4 steel kiln-feed tanks and four 125-ft. kilns using pulverized coal as fuel.—A. J. HOSKIN

A thermal study of the manufacture of cement. H. LEFORT. *Rev. materiaux construction trav. publics.* (France) 1930. No. 248, p. 171-6.—Another heat balance calculation.—F. O. ANDEREGG

The properties of the cement bacillus and its development during disintegration of concrete in sulfate waters. A. GUTTMANN and F. GILLE. *Tonind. Ztg.* (Germany), 1930, V. 54, No. 46, p. 759-62.—There can be no doubt about existence of calcium aluminum sulfate as the cement "bacillus." The best protection consists in making a dense and rich concrete. —F. O. ANDEREGG

Viscosity of setting cement. Immersion filter method. K. E. DORSCH and A. DEUBEL. *Kolloid Zeitschrift* (Germany), April, 1930, V. 51, No. 1, p. 180-6.—Investigations were carried out at Institute of Technology in Karlsruhe (Germany) concerning viscosity of cement mixed with water for normal consistency. Tests made with usual method did not give reliable results on account of sedimentation. New immersion filter method was derived, which allows measurements of viscosity of cement during period of setting with accuracy of 5 per cent. Progress of setting of a number of different cements was studied. During the first time of setting (0-60 min.) viscosity increases rapidly. This period is followed by constant viscosity for ½ hour. After this time viscosity increases again. Results of experiments agree with theories of setting.—A. E. BEITLICH

Annual meeting of German Portland Cement Manufacturers Association, March, 1930. *Zeitschr. angew. Chem.* (Germany), May, 1930, V. 43, p. 355.—The following papers were presented: (1) Gustav Haegermann: Sintering of cement raw materials. Rate of combination in burning cannot be judged from appearance or shrinkage of clinker. Best temperature for sintering of cement raw materials is between 1275° and 1295° C. (2) Eitel: Hydrates of tricalcium-aluminate. Thorvaldson's results on disintegration of cement by sulphate waters are discussed. (3) W. A. Roth: Thermochemistry of cement. Heat of reaction, which is formed when cement raw mix is burned with paraffin and compressed oxygen in a calorimeter, was calculated. Investigations were made to study heat of formation and heat of setting by dissolving cement raw mixes in hydrofluoric and hydrochloric acid. (4) Hans Kuehl: Relation between strength of cement and fineness. Tests indicated that strength of cement does not increase appreciably when particle size drops

below 20 microns. Suggestions are given for manufacture of high strength cement by certain combinations of particle sizes. (5) F. Krauss: Importance of complex compounds. (6) H. Burchartz: Effect of storage on cement. Discussion of the theory by Gensbaur. (7) R. Nacken: Heat of formation of silicates. Heat of solution was determined by dissolving in mixtures of hydrochloric, hydrofluoric and nitric acid. (8) L. Forsen: Gypsum and other retarding agents. Theory of setting and hydration of cement is presented. (9) Otto Graf: Concrete disintegration in aggressive waters. Paper discusses resistance of different kinds of cements against aggressive waters. Influence of fineness is cited and suggestions for concrete protection are given. (10) A. Hummel: Fineness modulus of aggregates. (11) A. B. Heller: Improvements in mill practice. New type of mill for closed circuit grinding is described.—A. E. BEITLICH

The first Dutch cement works, at Saint Pietersberg, near Maestricht. *Revue Materiaux Construction trav. publics* (France), Jan., 1930, No. 244, p. 19-23.—This is a works for treatment of chalky marl obtained at Saint Pietersberg, and turns out annually 300,000 tons of cement. (1,000 tons of clinker per diem). The chalky marl is treated together with imported plastic clay (levigation). The powdered material and the slime are transported with the aid of pneumatic apparatus. All the most up to date implements are used for crushing, grinding and mixing process. Coal is also dried and treated with success.—A. SIZE

Enlargement of the Portland Cement Works at Groschowitz (Upper Silesia). *Revue Materiaux Construction trav. publics* (France), Feb., 1930, No.245, p. 74-76. A description of alterations to cement works in Upper Silesia (manufacturing artificial portland cement by the wet process) to increase production from 200 tons to 500 tons per day. Works are easily controlled and output very regular. Nearly all the machinery is operated individually. —A. SIZE

Suggestions for selection of lining for cement kiln, especially for rotary kiln. OTTO FREY. *Zement* (Germany), May, 1930, V. 19, No. 21, p. 492-3.—In selecting suitable linings for cement kilns it is necessary to make chemical analysis of raw material and firebrick. Clinkering point and melting point must be determined. Clinkering point of lining must be more than 50° C. higher than clinkering point of raw mixture.—A. E. BEITLICH

The rotary kiln and waste heat boiler. S. STEINER. *Tonind. Ztg.* (Germany), 1930, V. 54, No. 52, p. 858-60. A review of the arguments for and against the waste heat boiler in connection with the rotary kiln.—F. O. ANDEREGG

Portland cement plant "Kursachsen" in Carlsdorf (Germany). *Zement* (Germany), May, 1930, V. 19, No. 20, p. 464-7.—Plant was built in 1928 in Carlsdorf a. U. near Naumburg a. S. and was enlarged in summer 1929. Output is 500 t. daily. Location of plant is favorable with water way connections to northern and central parts of Germany. Raw materials are limestone and clay. Quarry is situated 500 m. from the plant. Stone is transported by aerial tramway to crusher; discharge of cars is automatic. Belt conveyer delivers crushed materials to raw mill, where both raw materials are stored in bins. Two table feeders at bottom of bins control mixture. Both feeders are driven by same motor, speed of which can be regulated. Raw mixture and water enter two three-compartment-mills. Two special bins with table feeders are installed to add admixtures for manufacture of special cements. Slurry runs to four concrete tanks with conical bottoms. Elevator buckets transport slurry from outlet of tanks to distribution arrangement on top. Compressed air provides good mixing. From there raw mixture is delivered to kiln feeders which are regulated by individual motors. Plant has two Unax kilns with coolers. Two finishing mills, each one having four chambers, are used for cement grinding. Screws and elevators bring finished cement to four storage

bins of reinforced concrete. These are provided with flat bottoms, and cement is moved from bins to packers by pumping system. Latter enables mixing cement from different bins. Coal arrives at plant in carloads and is fed directly to crushers. Conveyer belt carries material to two coal dryers and storage bins. Special consideration is given to perfect dust precipitation. Power of 30,000 volts is furnished to plant from outside and is transformed to 500 volts in own power station. Plant equipment and machinery were installed by F. L. Smidth & Co. A/S, Kopenhagen and Luebeck. Several photographs accompany article.—A. E. BEITLICH

Cement chemistry in theory and practice. "Zementchemie in Theorie und Praxis." HANS KUEHL. 1929. Editor: *Zement und Beton*, G. M. B. H., Berlin, 92 pages. R. M. 4.50. Reviewed in *Zement* (Germany), May, 1930, V. 19, No. 18, p. 432.—Subjects of book are: ways of cement research, theory of cement burning, constitution of clinker, hardening problem and chemistry and technique of high early strength cements. Book is of great value to cement research workers and cement manufacturers.—A. E. BEITLICH

Heat of mill and setting time of cement. K. KOYANAGI. *Zement* (Germany), May, 1930, V. 19, No. 20, p. 467-9.—Investigations were carried out in Japan with gypsum which was heated at temperatures from 130-200° C. for half an hour. Content of SO_3 and loss on ignition were determined. Treated gypsum was mixed with clinker in proportions from 0.9-2.5 per cent SO_3. Setting tests showed that setting time decreases with increasing temperature of heating gypsum. When SO_3 content is lower than 1.2 per cent, cement never shows quick set. Difficulties were overcome by keeping SO_3 content between 0.9 and 1.2 per cent. (cf. *Zement* (Germany), Nov., 1929, V. 18, p. 1348-50; *Journal Amer. Concrete Inst.*, Jan., 1930, p. 3.)—A. E. BEITLICH

Rotary kiln calculation. A. B. HELBIG. *Zement* (Germany), May, 1930, V. 19, No. 19, p. 440-4.—Author gives detailed calculation of heat economy of rotary kiln and discusses following points: heat consumption for burning off carbon dioxide of raw mixture, for vaporization of water, heat loss due to conduction and radiation in kiln and cooler and heat of formation of clinker. Utilization of rotary kiln waste gases can be made very economical when difficulties caused by dust are overcome. Automatic recording thermometers and carbon dioxide meters should be installed on every kiln. Conditions are cited which lead to wrong registrations on those apparatus.—A. E. BEITLICH

Power and heat economy in cement industry. Directions for examination and valuation of kilns and burning processes. JAKOB KOCH. *Zement* (Germany), April, 1930, V. 19, No. 14, 15, 16 and 18, p. 324-8, 348-53, 373-7 and 418-23.—Burning process in cement kiln consists of number of separate processes. Author illustrates operating conditions by means of graphs. Dry and wet processes are discussed. Formulas are given for calculation of heat consumption, amount, temperature and heat content of waste gases and their dependence on the operating conditions. Relations are shown between amount of waste gases, heat consumption and excess of air and suggestions are made for economic utilization of waste gases. Efficiency of waste heat boiler system is calculated for dry and wet process, and influence of vapor pressure on economy is illustrated. Several tables show amount of waste gases and their temperature in both processes by different heat consumption and also necessary amount of heat for vaporization of water dependent upon water content in raw material. One single diagram is given which shows amount of gases for fuels with any calorific value, any coal consumption and any excess of air. Same diagram enables one to read heat content of waste gases, their temperature and preheating temperature of combustion air for any heat consumption for burning of dry raw mix, for any water content in raw mix and for any loss in heat by radiation and in clinker. A number of examples of practice are given which illustrate the use of these diagrams.—A. E. BEITLICH

Importance and evolution of the concrete industry in Italy. ANTONIO PESENTI. *L'Industria Italiana Del Cemento* (Italy), Dec., 1929, p. 4-5.—Cement industry started in Italy at about same time as in United States and at first proceeded on an empirical basis with correspondingly poor product. Wars and political vicissitudes retarded development, despite presence of abundant raw material, until 1870 when national unity was achieved. First plant for production of artificial portland cement was built in 1873, followed rapidly by numerous plants in Casalese, Bergamasco, Veveto, Emilia, Toscana, Umbria and elsewhere. In 1904 discovery of rich beds of marl led also to erection of plants along the Adriatic coastline. In 1898 and 1904 there were severe depressions but in 1904 began a period of prosperity which ended with the World War. Old plants were enlarged and new plants constructed and scientific methods were introduced. After the war there was great expansion of cement industry so that it now is one of most important industries of country representing a capital employed of 1,100,000,000 lire. Production increased until 1927, since which time it has remained practically stationary. Manufacturers however, have continued to improve their plants and processes and Italia cements are equal to the best foreign products, including special early hardening cements. The Federazione Nazionale Fascista del Cemento and the Societa' Incremento Applicazioni Cemento are recently formed organizations to encourage improvement in manufacture and to promote use of cement.—C. G. CLAIR AND M. N. CLAIR

Rotary kiln calculations. HANS BUSSMEYER. *Zement* (Germany), May, 1930, V. 19, No. 22, p. 522-4.—Author criticizes article by A. B. Helbig and contests his statement that normal rotary kiln with waste heat recovery is superior to "Lepol"-kiln manufactured by Polysius, Dessau (Germany). Several calculations of Helbig are corrected and tables recalculated. It is claimed that the "Lepol"-kiln has several advantages over any other rotary kiln. Heat calculations for both kinds are given and heat economy of "Lepol"-kiln is especially characterized. (c. f. A. B. Helbig, *Zement* (Germany), May, 1930, V. 19, No. 19, p. 440-4.)—A. E. BEITLICH

Use and abuse of building materials. Cement. A. M. GILES. *Builder* (England), May 2, 1930, V. 138, No. 4552, p. 870; No. 4553, p. 928; No. 4554, p. 969; No. 4556, p. 1013.—Article opens with brief history of development of cement manufacture and its composition. Cement contains 60-65 per cent lime, 20-25 per cent silica, 6-10 per cent alumina, small percentage of oxides of iron, and smaller percentages of other impurities. In setting, it is assumed that silicate of lime breaks down from 3 $CaO.Si\,O_2$ to a compound having one molecule of lime, the other molecules combining with water to form hydrate of lime. Setting time may be delayed by combination of sulphur anhydride or SO_3 with lime to form lime sulphate. Therefore the percentage of sulphur anhydride should not exceed 2.75 per cent. Ratio of lime (after amount to satisfy sulphur anhydride has been deducted) to sum of silica and alumina content should not be greater than 2.9 or less than 2. Manufacture. Main points of interest after excavation of raw material are crushing and grinding, and in wet process, final adjustments as to composition of slurry. Slurry passes down rotary kilns and its temperature rises to 3000° F, causing it to be first dried and then calcined. Resulting clinker is ground to finished cement. Samples for test are required by British Standard Specification to be taken from quantities of not more than 250 tons. The main tests required are for fineness of grinding, setting time, chemical composition, tensile strength of neat cement, and of mixture of cement and sand, and finally soundness. In addition to usual tests for setting time, rough method suggested by Dr. Faber in the Concrete Year Book is described. A 3-in. square pat, 1 in. thick should be placed on a piece of iron, slate or glass. Its progress of setting should be observed and in 18 to 24 hrs. it should have hardened sufficiently to resist any

impression by thumb-nail, while in 48 hours it should not be easy to break pat with fingers. Although there is considerable decrease in volume when dry ingredients of concrete are mixed with water, when concrete has set there is expansion which may not show for several years. Soundness test gives a measure of effect of this post-setting expansion. Expansion comparable with that resulting from long period may be obtained in a few hours by placing the cement in boiling water. The sample should be aerated by being spread out in a layer not more than 3 in. thick and left for 24 hours in a temperature of 58 to 64° F. The hardness test is well known as the "Le Chatier" test. A simpler method consists of placing a 3-in. diameter pat on a 4-in. sq. plate of glass. This is kept in moist atmosphere for 24 hours and then placed an inch above boiling water for about 5 hours. After cooling it can be removed from the glass, and should have retained its lens shape and give a clear sounding ring when struck with knuckle or lead pencil. Cement with high alumina content is quick setting and although, on account of its composition it does not conform to the standard specification, its strength is quite up to standard. Much heat is evolved during setting—an advantage in frosty weather—but it should be kept wet in order to make up for the water lost by evaporation. Care must be taken to avoid contamination by lime or ordinary portland cement. For white cement, iron oxide must be absent.—JOHN E. ADAMS

Hardening of Sorel cements. A. KRIEGER. *Tonind. Ztg.* (Germany), 1930, V. 54, No. 36, p. 577-8.—The compound, $2MgO.MgCl_2.9H_2O$ is always present, but other substances in a gel form are also there for ratio of $MgCl_2$:$Mg(OH_2)$ may vary from 1:3 to 1:15. It is suggested, however, that initial hardening is due to this compound. Strength seems to depend upon the water-cement ratio.—F. O. ANDEREGG

Gaize cement for sea work. G. BAIRE. *Rev. materiaux construction trav. publics* (France), 1930, No. 248, p. 168-70.—Gaize is a siliceous material of sedimentary origin which is about $\frac{1}{3}$ soluble in 20 per cent KOH after 20 hours of cold contact and 4 at 50 to 65° C. Exposure to sea water seems to increase the amount of active silica. A good cement is obtained on grinding one part of gaize with two of portland cement clinker plus a trace of gypsum. Its use was interrupted by the war, but certain experimental installations in sea water in 1910-11 have stood up so well that its use in sea water has been revived.—F. O. ANDEREGG

Blast furnace cements. A. O. PURDON. *Rev. materiaux construction trav. publics* (France), 1930, No. 249, p. 205-12.—Blast furnace cements, made by grinding portland cement clinker with blast furnace slags of proper composition, are giving very good results. Early strengths are lower than those of portland cement but improve later. Volume change is small; resistance to salt solutions is good; while danger from sulfur in slag is regarded as negligible.—F. O. ANDEREGG

Researches on action of inhibitors of setting of cements. *Rev. materiaux construction trav. publics* (France), Feb., 1930, No. 245, p. 50.—Berger gives following conclusions from researches carried out with 4 samples of anhydrite, one sample of gypsum, one of plaster and cement clinkers. To obtain cement which sets normally with anhydrite, it is necessary to use more SO_3 than with gypsum or plaster of Paris. The plasticity of cement which contains anhydrite is less than that of a cement in which gypsum is used. The fineness of the anhydrite has considerable importance with regard to plasticity of cement, but various qualities of natural anhydrite do not present any distinctive features. It is preferable to crush slow setting component separately from clinker. Quantity of SO_3 existing in solution of "inhibited" cement is

proportionate to solubility of inhibitor used. This aspect of subject deserves further study as results obtained so far are not final.—A. SIZE

Dosage of soluble silica in pozzuolanic cements. BAIRE. *Revue materiaux construction trav. publics* (France), Feb., 1930, No. 245, p. 61-62.—Method indicated by Chesneau is only suitable for estimating soluble silica in unmixed cements; for pozzuolanic cements the results obtained are not satisfactory, any more than in regard to cements obtained by mixing pozzuolane with portland cement. Author recommends combining hydrochloric acid method and carbonate of soda method for mixed cements, as ensuring complete dissolution. The mixtures contain at the same time silicates and non-combined silica.—A. SIZE

Hydrates of tricalcium aluminate. WILHELM EITEL. *Zement* (Germany), April, 1930, V. 19, No. 17, p. 394-9.—Discussion of research work on calcium-aluminates in connection with work done by Th. Thorvaldson. Studies concerned the volume changes of test pieces in sulphate waters. Hydrates of the tricalcium-aluminate were examined and reactions with water studied. Four different hydrates could be identified and their optical properties determined. These are hydrates with 6, 8, 10½ and 12 molecules of water. The heat of solution of these compounds is cited. A great number of references are given.—A. E. BEITLICH

MISCELLANEOUS

Report on accident during application of protective coating on concrete. DR. RICHARD GRUN. *Zement* (Germany), April, 1930, V. 19, No. 16, p. 383-4.—A water tank with a capacity of 100 cu. meters was provided with a protective inner coating of a bituminous preparation. Evaporating solvents formed with air explosive mixtures which caused death of two laborers. Following precautions should be observed: coating material should not contain any substances with low boiling point; flash point should be determined, smoking and open lights must be prohibited during and after application of coating. Sufficient ventilation must be provided for in closed chambers and tanks.—A. E. BEITLICH

Contribution to knowledge of old mortars. KARL BIEHL. *Tonind. Ztg.* (Germany), 1930, V. 54, No. 51, p. 839-41; No. 53, p. 877-8.—Samples of mortar from German buildings ranging from the 16th to 19th centuries have been studied. Most of them were quite fat. Trass was found in only one mortar and then in small amount. From Persia one mortar was of gypsum without sand, while one of later date was fat lime mortar containing ground brick, showing influence of Romans.—F. O. ANDEREGG

Magnesia cements. *La Revue Industrielle* (France, Feb., 1930; reviewed in *L'Industrie Chimique* (France), June, 1930, V. 17, No. 197, p. 406.—Most important magnesia cement is "Sorel"-cement, which consists of mixture of magnesium oxide and magnesium chloride. Variations in cement are due to composition of magnesium oxide, which is obtained by calcination of magnesite or magnesium carbonate. Good magnesite, which is used for very pure cements, is calcined at 500° C., while magnesites containing ferric oxides need a temperature of 800° C. Ignited material is mixed with different materials such as saw dust, asbestos fibres, sand, cork or diatomaceous earth. These mixtures so obtained are mixed with solution of magnesium chloride of 22° Be. Author describes also some other methods of manufacture of magnesia cements.—A. E. BEITLICH

Refractory mortars. O. PHILIPP. *Chem. Fabrik* (Germany), 1930, p. 86; reviewed in *L'Industrie Chimique* (France), June, 1930, V. 17, No. 197, p. 405.—Refractory mortar, which is to be used for construction of firebrick linings, must have sufficient adhesive properties and should not have a higher porosity after exposure to fire than the bricks. First condition is fulfilled when fire clay is used with or without binder like sodium silicate or dextrin. Refractory mortars, which have to stand very high temperatures are mostly made from the brick material itself by grinding and mixing powder with suitable cement like bentonite. Instead of cement one can use mixture of starch solution and glass or quartz powder.—A. E. BEITLICH

Bauxite production in France. B. CHARRIN. *Le Ciment*, May, 1930, p. 190.—Bauxite deposits are located in Southern France. Of these the Var yielded about 520,000 tons in 1928 and the Hérault 110,000 tons. France leads in production of bauxite with an annual output of over 600,000 tons. United States production, highest in 1920, has dropped to 300,000 tons (5th place) due to inferior quality and higher cost of production. Fifty per cent of bauxite produced is utilized in aluminum industry; 30 per cent is consumed by alumina cements; the rest used in the chemical industries. The world's production of aluminum demands about 850,000 tons of bauxite a year. A conservative estimate of the bauxite still available for exploitation in France is as follows: Var with 8 million tons; Hérault with 5 million tons; Bouches-du-Rhone with 2 million tons and Ariege with one million tons. Half of the above deposits contain a maximum of 7 to 8 per cent silica, a limit acceptable in the manufacture of aluminum and alumina cement.—MRS. M. A. CORBIN

Chemical composition of bauxites. V. CHARRIN. *Génie Civil* (France), Jan. 18, 1930, V. 18, No. 3, p. 63-64.—Red bauxites which are very abundant in France, have just begun to find very wide application in connection with cement. Alumina cements require a mineral not surpassing 8 to 10 per cent of silica and containing 30 per cent of iron and a proportion of 50 per cent at least of alumina. France has most and best quality bauxites, but in view of the ever-increasing demand for them for making aluminium and alumina cements it would be necessary to regulate the industry, and to amend present laws with regard to quarrying (law of 1810).—A. SIZE

Hydration of calcined gypsum. W. C. HANSEN, *Ind. Eng. Chem.*, June, 1930, V. 22, No. 6, p. 611-613.—A study was made to supply satisfactory explanation of accelerating or retarding action of soluble substances upon setting of gypsum-water pastes. Time-temperature curves obtained with calcined gypsum in various salt solutions indicated that controlling factor in setting is rate at which precipitation of gypsum takes place from its supersaturated solution. This theory was corroborated by demonstrating that foreign salts have a marked effect upon rate of gypsum precipitation from mixed solutions of calcium nitrate and ammonium sulfate. It is possible that effects of foreign substances on setting of portland cement also may be explained by their effects upon rate of precipitation.—ROY N. YOUNG

PROPERTIES OF CONCRETE

Trouble of concrete. *Australasian Eng.*, May 7, 1930, V. 30, No. 167, p. 20.—Contraction of air hardened concrete is about three times greater than that of concrete hardened under water. Sulphur in aggregate may also cause excessive expansion. An example is given of 3-in. concrete floor which pushed a wall over 2 in. in six months. Excessive heat may cause disintegration; a concrete foundation to a furnace, separated from the actual fire by 2 courses of 9 in. brickwork could, after a time, be broken away with the fingers. Broken firebrick aggregates are satisfactory if ample time is allowed for maturing and hardening delayed by placing wet bags over concrete. Finishing surfaces of

floors should be placed while under layer is still green, or there will not be proper cohesion between the two layers.—JOHN E. ADAMS

New comparisons between tensile, flexural and compressive strengths. R. FERET. *Rev. materiaux construction trav. publics* (France), 1930, No. 244, p. 1-4; No. 245, p. 52-60; No. 246, p. 83-95; No. 247, p. 127-33.—Search of literature has brought to light several comparisons of tensile, flexural and compressive strengths. Results are plotted and in general it is found that first two properties are proportional to each other and to the $\frac{2}{3}$ power of compressive strengths. Some exceptions exist, however. On plotting the ratio between the flexural and compressive strengths against water-cement ratio a number of straight lines were found. In general, alumina cements have lowest tensile-compressive ratios, followed by the portland cements which set lime free, and then the pozzuolanic cements. With moist storages and within certain limits of aggregate compositions, the water-cement ratio is found to be most important in controlling the strengths. On storing in corrosive waters, like $MgSO_4$, results vary with nature of cement.—F. O. ANDEREGG

The impermeability of concrete to water. C. R. PLATZMANN. *Tonind. Ztg.* (Germany), 1930, V. 54, No. 40, p. 676-7; No. 43, p. 718-20; No. 45, p. 748-9.—After review of literature, importance of grading of aggregate is pointed out. Various methods of surface hardening and surface protective coatings are discussed.—F. O. ANDEREGG

Use of concrete and reinforced concrete on the railways. M. F. B. FREEMAN AND M. E. KRICK. *Génie Civil* (France), Feb. 8, 1930, V. 96, No. 6, p. 144.—Concrete and reinforced concrete are widely used for various railway undertakings owing to low cost of upkeep and their refractory character. But it is necessary to keep a close watch on changes caused by time, etc., and to take precautions in regard to calculation of weights to be supported by bridges. Smoke of locomotives has no deleterious influence on concrete provided surface is smooth and has no fissures. Iron and steel bars must be sufficiently far from surface of concrete to avoid attack by rust.—A. SIZE

Theory of the expansion of liquid cements. HENRI LAFUMA, *Rev. Mat. Constr.*, Jan., 1930, No. 244, p. 4-8.—Swelling of quick lime by slaking is due to the spontaneous pulverization of the lime and increase of absolute volume of solid phases during reaction. Apparent volume is enormously increased by this process. It is necessary, in order to improve mortars, to eliminate these reactions by dissolving solid salts beforehand. Author studies successively chemical disaggregation of aluminous and hyper-aluminous portland cements; setting of tempering cements; swelling action which is exercised on mortar by presence of aluminium plates, and the expansion of quick setting mortars.—A. SIZE

Concrete; effect of aggressive liquids on concrete and possibilities of concrete protection. M. GRUEN. *Chimie et Industrie* (France), Jan., 1930; reviewed in *L'Industrie Chimique* (France), June 1930, V. 17, No. 197, p. 406.—In general all acids attack concrete. This effect increases with concentration of acid. Gaseous acids too have corrosive properties. Certain salts are able to attack concrete. Sulphates have the tendency to form calcium-sulphoaluminates. Fatty substances corrode concrete. In order to prevent concrete attacks, one can use suitable mixtures, or protect surface with coatings. Grain size of sand plays important role. Coating may be either bitumen, tar or some varnish.—A. E. BEITLICH

Contribution to valuation of certain mixed storage of cement test pieces for practice. H. BURCHARTZ. *Zement* (Germany), May, 1930, V. 19, No. 21 and 22, p. 488-92, 510-5.—Investigations were made of variations in strength of test pieces under different storage conditions. Five different kinds of cement: one high-early strength cement, one portland cement burned in rotary kiln, one portland cement burned in shaft kiln, one iron-portland cement and one blast furnace cement were studied. Normal strength tests were made

under varying storage conditions, and gain or loss of water during storage was determined from each test piece. Strength of test pieces which are stored in water after preceding normal storage decreases in general. Tensile strength is more effected than compressive strength, especially during short water storage. —A. E. BEITLICH

Effects on concrete. "Einfluesse auf Beton." A. KLEINLOGEL, F. HUNDESHAGEN AND OTTO GRAF. 3rd edition, 1930, Wilhelm Ernst & Sohn, Berlin (Germany), R. M. 39.50; reviewed in *Zement* (Germany), May, 1930, V. 19, No. 19, p. 456.—Book illustrates possibilities of corrosion of concrete, danger and damage through chemical agents, aggressive waters and other unfavorable conditions and shows ways to prevent such damage by proper precautions. Many references are given.—A. E. BEITLICH

Building protection. "Der Bautenschutz." (New journal) Wilhelm Ernst & Sohn, Berlin (Germany); reviewed in *Zement* (Germany), May, 1930, V. 19, No. 18, p. 432.—Journal appears together with *Beton und Eisen* (Germany), and brings articles concerning new tests, investigations and experiences in the field of concrete and effect of water, weather and fire on concrete.—A. E. BEITLICH

Equipment for testing the water impermeability of concrete. HANS HECHT. *Zement* (Germany), May, 1930, V. 19, No. 20, p. 472-3.—Author describes apparatus similar to one designed by Otzen. Water pressure is kept constant by means of compressed air tank which is connected with large water reservoir. Twelve test pieces can be exposed simultaneously to different pressures. Apparatus can also be used for tests with aggressive waters and solutions and is entirely independent of any stationary water line. Test pieces up to 30 cm. in diameter can be tested. Pressure can be varied up to 20 atm.—A. E. BEITLICH

Concrete and reinforced concrete in fires. New experiences. A. WEISS. *Zement* (Germany), May, 1930, V. 19, No. 18, p. 424-7.—Behavior of concrete walls and ceilings during recent fires showed again superiority of concrete for fire resistance. Casings of iron columns should not be thinner than 10 cm.—A. E. BEITLICH

Control practice in reinforced concrete construction in erection of warehouse No. VII in Free Port of Stettin. (See FIELD CONSTRUCTION—Buildings.)

Blast furnace cements. (See MATERIALS—Cement.)

ENGINEERING DESIGN

Welded trusses developed for bridge floor reinforcing. H. M. BRINGHURST. *Eng. New Record*, July 3, 1930, V. 105, No. 1, p. 8.—Roadway slab reinforcing used on the new bridge over the Ohio River at Louisville, Ky., and on the Ambassador Bridge at Detroit is interesting example of truss-type reinforcement, and represents first use of arc welded material on bridges of this size. Reinforcing units are light trusses of Warren type made up of round bars. Web is formed by a continuous bar bent to a zig-zag shape and welded at bends to top and bottom chords, each of which consists of two straight round bars. Bars from which trusses are fabricated are furnished by mill in coils and are straightened at plant in straightening machines to remove mill scale. Webs are bent on compressed air machine and are spliced to facilitate handling. The bars are then assembled in a jig and each joint is electrically arc welded by hand. Special care is taken to avoid distortion from application of heat. After removal, each joint is tested with a pinch bar. At irregular intervals, trusses are tested to destruction as additional check. Specimens of long span fail from buckling of the top chord and those of short span fail by buckling of the web. Weld failures were not obtained in any tests.—D. E. LARSON

Design of road bridges. C. S. CHETTOE. *Roads and Rd. Constr.* (England), May 1, 1930, V. 8, No. 89, p. 149.—Rigid Frames. This article continues with discussion of rigid frames of semi-elliptical and parabolic type of arch frames which meet their abutment slabs at an almost vertical angle. They are more economical in material than true rigid rectangular frames and have better appearance. Attention is drawn to difference between active pressure and passive pressure exerted by earth in case of retaining walls, the latter being, when maximum, much greater than former. According to Rankine, maximum passive horizontal pressure bears same ratio to downward pressure at any point, as downward pressure bears to active horizontal pressure. Although assumption that pressure is horizontal may hold when walls are constructed in timbered trench against vertical surface of consolidated earth, it is not true when filling is piled behind wall. In general, it is sufficient to design for active pressure. Passive pressure on frame sides reduced crown stress but will increase moments at corners. For very flexible frames it may be advisable to allow for some passive pressure. In culvert design, the more flexible the culvert the less weight of earth carried by it. Conditions will be more favorable if culvert is excavated out of existing ground up to haunches. Increased side pressure due to steep sides to a ravine has occasionally caused failure of culverts constructed in it. Filling should be brought up equally on both sides, otherwise allowance must be made in design. Reference is made to Kleinlögel's book for cases of side loadings.—JOHN E. ADAMS

A new department store in Frankfurt a. M. (Germany). RUDOLF KLAR. *Zement* (Germany), May, 1930, V. 19, No. 18, p. 431-2.—Building is located in business center and limited space was available for transportation and storage of construction materials. Foundations were placed on bad underground which allowed only 2 kg./cm.^{2} pressure. High early strength cement was used. Skeleton structure shows beams with span of 8 meters. A total of 8500 m^2 ceilings were placed. Ceiling of basement is reinforced concrete, one over first floor is crosswise reinforced Remy ceiling, rest are ordinary reinforced Remy ceilings. Cross sections of beams were made as small as possible for architectonical reasons and their reinforcements were made especially strong. Concrete test pieces gave 280 kg./cm^2. compressive strength after 12 days.—A. E. BEITLICH

Specifications of the German committee for reinforced concrete of September, 1925. "Bestimmungen des deutschen Ausschusses fuer Eisenbetom vom September 1925." 5. edition, 1930, Wilhelm Ernst & Sohn, Berlin (Germany), R. M. 1.80. Reviewed in *Zement* (Germany), May, 1930, V. 19, No. 20, p. 480.—Four parts deal with following subjects: specifications for reinforced concrete, concrete ceilings, concrete buildings and cube tests.—A. E. BEITLICH

Modern skeleton building in Kiel (Germany). WENZEL. *Zement* (Germany), April, 1930, V. 19, No. 16, p. 378-9.—Building is 112 m. long and is made without any shrinkage joints. Concrete was kept wet for 6 weeks by means of special sprinkler system and no visible shrinkage cracks could be observed after one year. Floor slabs, which have solid rib in center, have span of 6 m. and are 1.30 m. wide. They rest on 20 x 40 cm. concrete columns. Main floor consists of 14 cm. thick concrete slabs which are supported by 23 cm. thick continuous brick wall.—A. E. BEITLICH

The convention hall in Memmingen (Germany). WECHS. *Zement* (Germany), May, 1930, V. 19, No. 22, p. 521-2.—Description of construction of large hall in reinforced concrete. Building is 66 m. long, 26.50 m. wide and 12.50 m. high. Concrete columns have cross-shaped cross-section; they are 12 m. high and 1.05 and 1.50 m. wide. Side walls are solid and 25 cm. thick.—A. E. BEITLICH

Project of the dam of Tecamachalco. ADOLFO ORIVE ALBA. *Ingenieria* (Mexico), Feb., 1930, p. 60-61.—Results of an investigation made for Secretary of Communications to determine the location and design of dam to control Los Morales river are given. A survey was made to determine the underground conditions. A cross section of the site is given showing geological formation. The conglomeration clay formation near surface in some parts is said to be similar to that under right side of the St. Francis dam, which recently failed; so special precautions were considered necessary. Rubble or rock-fill type of dam was considered most adaptable to the conditions; but not enough materials were available; so gravity and arch-gravity dams of concrete were investigated. It was decided to build a gravity dam, designed assuming a pressure on the base varying from full head of water at upstream face and into line of vertical drains to zero at downstream face. The result of all forces was made to fall within middle third for both empty and full conditions. The coefficient of sliding was kept less than 0.70. A sketch of proposed cross section is given, which shows all important details. Section is of typical gravity kind of cyclopean concrete, four meters wide at top, 16 meters wide at the base, and 23 meters high. There is a series of vertical drains 10 centimeters in diameter spaced at two-meter intervals parallel to upstream face, and two meters from it. Drains are intercepted by an inspection and drainage gallery. Cut-off walls extend below the base of dam both at upstream and downstream sides. Purpose of permeable downstream toe being to prevent the movement of material if it becomes softened by the flow of water. A spillway opening is provided to take care of both the San Joaquin and the Tecamachalco excess flows. An emergency conduit 0.75 meters in diameter provides for emergency flows.—MILES N. CLAIR AND C. G. CLAIR

Design and economy of plain and reinforced concrete dams. E. PROBST AND F. TOLKE. *Zeitschrift Ver. deu. Ing.* (Germany), 1930, V. 74, Nos. 13 and 15.—Paper, presented at Second International Power Conference at Berlin, is brief review of various types of dams and problems encountered in their use. Dam cost is such large part of total cost of a hydroelectric project (29, 29 and 40% for three cases cited) that selection of most economical structure is important. Arched gravity dam is not recommended unless joints are to be grouted. Grouting is advised in spring when masonry is at its lowest temperature. Danger of uplift should not be underestimated. Drainage system will relieve uplift and may be considered as an additional precaution. It should not be considered in design, however, as its continued functioning throughout long life of dam is not certain. Rather arbitrary assumptions of gravity dam proportions are justifiable when uncertainty of stresses near base and force of uplift are considered. Base to height ratios used in recent practice (ten dams listed) indicate that while about 0.70 is used in United States and in Germany, more conservative values (up to 0.97) are common in other European countries. Larger section is not necessarily safer section, because of cracks from higher "secondary" stresses and from shrinkage. Wherever possible arch dam should be used rather than gravity dam. Some American and European types of slab and buttress dams are discussed from viewpoint of cost and durability. These types, compared to gravity and arch dams have advantage of clearly understood structural action. Thin reinforced sections, however, face possibility of corrosion of steel. Condition of foundation rock is of primary importance to safety of structure and should be thoroughly investigated. Proper care is not always used to obtain concrete that resists soakage and frost action. These properties may sometimes be more important than a high compressive strength. Large model tests and observations on existing structures are recommended for increasing knowledge of dam construction. Formation of an international bureau of records on dams is desirable.—A. A. BRIELMAIER

Concrete and reinforced concrete for water structures. F. HIRT. *Zement* (Germany), May, 1930, V. 19, No. 20, p. 478-80.—Draining of large district in German lowlands and necessary concrete structures are described. Total area to be drained was 40 million square meters. Deepest part lies 1.43 m. under sea level. It was necessary to move 500,000 cu. meters ground. Channel was dug 15 m. wide at top and 10 m. at bottom, with fall of 1 cm. per 100 m. Highway bridge of reinforced concrete was built over channel. In order to lead water underneath a second channel a sewer was built of reinforced concrete. Sewer has three openings of 10 m² each. Total length is 31.50 m. Underground was soft sand. Third outstanding structure is pumping station near Borssum. Each of three rotary pumps delivers 8 cu. meters water per second and each is driven by two motors, one with 340 H. P. for pumping up to 2 m. and one with 600 H. P. for pumping from 2 to 6 m. Building rests on 400 wooden piles, each having diameter of 28 to 30 cm. Floor of building is made of reinforced concrete. Blast furnace cement was used for all constructions.—A. E. BEITLICH

The necessary reinforcements for reinforced concrete girder slabs. KURT BERNHARD. *Zement* (Germany), April, 1930, V. 19, No. 16, 17, 19 and 20, p. 379-83, 405-9, 447-52 and 474-8.—Formulas and equations are given for calculation of necessary reinforcements for girder slabs. Steel coefficient can be calculated and amount of steel determined for slabs of any cross section. All stresses are analyzed. Examples show calculations for single slabs and slab ceilings. Special consideration is given to different fields, end and center fields, with varying number of supports.—A. E. BEITLICH

Simplified calculations of flexible slabs. "Die vereinfachte Berechnung biegsamer Platten." MARCUS. 2nd edition. Julius Springer, Berlin, 1929, R. M. 11.00. Reviewed in *Zement* (Germany), April, 1930, V. 19, No. 17, p. 410.—Book gives calculations and describes stresses in all kinds of slabs and ceilings, and examples show that simplified formulas are well suited to the calculation of such work.—A. E. BEITLICH

Moments in continuous slabs and their reinforcements. SCHNEEMANN. *Zement* (Germany), May, 1930, V. 19, No. 21, p. 497-9.—Calculations are given, which show different moments in continuous slabs. Necessary change of standard specifications which increases support moments and reinforcements is suggested.—A. E. BEITLICH

Reinforced concrete ties after system Emperger. *Zement* (Germany), May, 1930, V. 19, No. 21, p. 499-502.—Weight of wooden ties is in general 75 kg., while concrete ties weigh 150 kg. This greater weight is more suitable to stand high vibrations. A special type of concrete ties is described, which consists of three parts. Transportation and placing of these ties is easier than ties consisting of one piece only. Reinforcements provide flexible connections of three parts. Iron parts are protected against rust by coatings or special arrangements. Drawings and photographs show all details, and practical experiences are given.—A. E. BEITLICH

Nomogram for determining the area of longitudinal steel. JORGE QUIJANO. *Ingenieria* (Mexico), Jan., 1930, p. 37.—A simple alignment or nomographic chart, one of a series of such charts for use in reinforced concrete design, solving the relation $A_s = pA_c$. Left hand scale or line Ac, middle scale As, and right scale p. All in metric units. Explanation of use is given on full page chart.—MILES N. CLAIR AND C. G. CLAIR

Nomogram for calculating bond stress. JORGE QUIJANO. *Ingenieria* (Mexico), Jan., 1930, p. 30-31.—A simple alignment or nomographic chart, one of a series of such charts for use in reinforced concrete design, solving the relation $uEo = Vb$. Left hand scale of line $\frac{u}{V}$, middle scale $\frac{As}{b}$ and right scale

diameter of bars. Explanation and examples of scale are given for determining various factors. All in metric units.—MILES N. CLAIR AND C. G. CLAIR

High unit stresses recommended for concrete-cased I-beams. *Eng. New Record*, May 15, 1930, V. 104, No. 20, p. 798-799.—A recommendation for 24,000 lb. unit stress in steel I-beams of floor framing when cased in reinforced concrete and covered with slab of same material is main conclusion of report presented on May 12 to Western Society of Engineers by committee which, in co-operation with Chicago building department, has conducted tests on floor construction of this type. Recommendation applies to I-beams up to 24 in. in depth when wrapped in steel wire fabric or mesh and incased in rectangle of concrete with minimum covering of 2 in. on flanges of I-beam and when used in connection with concrete floor slab not less than 2½ in. thick above top of flange of I-beam. Committee presented following facts based on study of number of tests: (1) Concrete and structural steel act together to form composite beam. (2) Influence of concrete prevails under vibration and impact. (3) Observed stresses in steel and deflections in slab are far below those computed on assumption that entire load is taken by steel alone. (4) Considerable economy in support of live loads may be obtained by utilizing joint action of concrete and steel. (5) Within practical limits composite beam conforms to theory and may be designed by methods analogous to those used in case of reinforced concrete T-beam. (6) Added strength of concrete may be taken advantage of in design by simple method of adopting higher unit working stresses in steel and then, with these stresses, calculating steel alone.—D. E. LARSON

Layout and construction of a new wet-process cement plant in Texas. TERRELL BARTLETT. *Eng. News Record*, May 29, 1930. V. 104, No. 22, p. 889-893.—Structural and manufacturing features of recently completed wet-process cement mill near San Antonio, Texas, for Republic Portland Cement Co., involve the following factors of interest: site selection; easily available quarry material in one place; layout of plant to reduce costs to a minimum; use of an unusual amount of concrete in the structures; concrete craneway frame; foundations on both rock and clay; large grinding capacity; close control, and silo construction for stock house. Because of the nature of the industry use of concrete was considered to be good policy wherever its cost would be equal to or less than steel. Steel is costly in Texas because of freight charges and concrete is cheap on account of labor conditions. The concrete craneway is unusual structural feature. In designing beams at the top it was necessary to consider impact of loaded crane weighing 50 tons and transverse thrust resulting from movement of crane trolley. In designing for wind load, each side frame was made laterally self supporting by use of buttress shaped columns on spread footings resting on rock. Columns of each frame are connected at mid-height by row of double-corbelled concrete struts. Analysis indicated that expansion joint was necessary in 300-ft. frame length to prevent undue temperature stresses in end columns.—D. E. LARSON

Curves for analysis of rectangular continuous beams with axes semi-circular in plan. ST. HESSLER. *Beton u. Eisen* (Germany), April 20, 1930, V. 29, Heft 8, p. 149.—Moment curves are given for torsion and direct bending in uniformly loaded beams, continuous over two, three, and four equal spans, for both fixed and hinged condition of end supports. Reference is made to article by author (cf. *Beton u. Eisen*, Heft 23, 1927) for treatment of theoretical basis of curves.—A. A. BRIELMAIER

Model tests of a flat-slab crossing structure. A. BUHLER. *Beton u. Eisen* (Germany), April 20, 1930, V. 29, Heft 8, p. 154.—This is brief summary of some tests made by Swiss Federal Railways. Model consisted of two spans with an overall length of 40 ft., width of 7½ ft. and height of 10 ft. Intermediate support was column with flared head and end supports were vertical

thin slabs with knee strengthened by bracket similar to part of center column head. Structure was loaded to failure with lead billets, and comprehensive set of observations made on several phases of structural behaviour. Among the conclusions the following points are mentioned: Cracks can not be prevented but may be kept small by proper distribution of steel. For usual steel ratios and concrete of fair quality ultimate load is dependent on yield point of steel. Shrinkage in concrete should be considered as about 0.05 per cent (Swiss Reinforced Concrete Standards call for 0.025 per cent). Use of reinforcement with high elastic limit is definite advance in concrete construction. Steel used in test showed elastic limit of from 57,000 to 77,000 lbs. per sq. in. From construction viewpoint flat-slab model was not very satisfactory. Knees at end supports were subjected to irregular stresses and early cracking. Exact placing of steel was difficult. E value for concrete showed a variation of ± 20 per cent, and decreased with increase in loading. It increased by about 6 per cent between ages of 1 and 3 months. Plane sections do not remain planar in highly stressed regions. Permanent deflections became evident at loads equal to two or three times design loads. Test cubes showed considerable variation in strength. Compressive and flexural tests of prisms showed permanent deformations at low stresses for young concrete. Possibility of permanent deformation as well as strength should be considered in determining time limits for removing forms.—A. A. BRIELMAIER

Successful reinforced concrete base for street railway tracks. I. O. MALL. *Concrete*, April, 1930, V. 36, No. 4, p. 13.—Methods followed in development of reinforced concrete track support in Canal Street, New Orleans, is combination of careful structural design supported by thorough tests under conditions simulating actual service. Roadbed structure consists primarily of reinforced concrete foundation to which rails are anchored by means of resilient rail anchorages. Foundation slab is shaped to form continuous girder beneath each rail and parallel to rail. The reinforcement in each of these girders consists of two ⅝ in. straight and deformed bars. The transverse reinforcement, extending the full width of slab and passing under each rail, is also of ⅝ in. round deformed bars. Two continuous longitudinal angles are embedded in concrete beneath and parallel to each rail. Rail anchorage units are fastened to these angles, which are held in parallel alignment by deformed straps welded to angles at points of contact. Tie rods, which extend from rail to rail, are covered with an asphaltic material to prevent their bonding to concrete. The cushion between rail and pavement along its side is accomplished by application of ¼ in. coat of asphalt to rail before concrete is placed. Transmission of shock from rail to concrete base is prevented by placing ¼ in. thickness of elastite immediately under base of rail, this strip being held in place by special wire clips. Further elimination of impact is obtained by means of a specially designed anchor plate or diaphragm.—C. BACHMANN

Concerning concrete and cement. R. E. *Roads and Rd. Constr.* (England), June 2, 1930, V. 8, No. 90, p. 196.—Referring to various Building Science Abstracts, the author stresses need for taking into account contraction stresses in reinforced concrete structures. Contraction per unit length varies from .0002 at three months to .0005 after six years, when setting stress will be 128 lb. per sq. in. For piles in water bearing soil, permissible load in tons is given by $P = Wh/(S + 1)$ where W is the weight of monkey in tons, h the fall in ft., and S the average penetration in inches for the last five blows. For power rams $P = Wh/(S + 0.1)$. Additional supporting power may be obtained by fitting to head of pile a 5 ft. square slab collar. Regarding cement guns, it is found that allowance for bulking should be made. If 1 to 3 dry sand mix is specified, 6 per cent moisture in pit run sand increases the bulk by 33 per cent and cement ratio will become 1 to 2¼ instead of 1 to 3. Furthermore it is found that when mix is applied to hard surfaces, 25 per cent of sand is lost through rebounding due to its velocity. Ratio of placed mix, then be-

comes 1 to 1.68. For coloring concrete, organic pigments should be avoided in favor of inorganic pigments such as ochres, umbers and oxides of iron, and synthetic colors like ultramarine. These, which should be finely ground as cement, do not decrease the strength.—JOHN E. ADAMS

ARCHITECTURAL DESIGN

Concrete architecture. WILLI LUTZ. *Zement* (Germany), May, 1930, V. 19, No. 19, p. 445-7.—Concrete in hands of an artist has many advantages over natural building materials. It has highest plasticity and durability and can be placed without joints. Molds can be used many times. No material waste. Selection of aggregates and admixtures allows variations of color and texture according to its purpose. Application of concrete in artistic architecture is illustrated on several reconstructions of big warehouse showing its use for facing of stairways and outside structures.—A. E. BEITLICH

Concrete beautiful. ERNEST O. BOSTROM. *Western Architect*, May, 1930, p. 72-73.—An architect's appreciation of concrete as an architectural medium combining strength with form and color.—REXFORD NEWCOMB

New concrete plastics. DAHL. *Zement* (Germany), June, 1930, V. 19, No. 23, p. 540-1.—Modern building construction uses more and more methods to provide outside of buildings with decorative finish and ornamental plastics from the hands of an artist. A number of photographs show what can be done along this line. Mtehods are described and suggestions for their application are given.—A. E. BEITLICH

Construction and shaping of skyscrapers of reinforced concrete. (See FIELD CONSTRUCTION—Buildings.)

FIELD CONSTRUCTION

BRIDGES

Erection of caisson of Poughkeepsie suspension bridge. H. G. SCHWEGLER. *Der Bauingenieur* (Germany), Jan., 1930, V. 11, No. 5, p. 71-2.—Highway bridge over Hudson river is 900 m. long with suspended portion of 450 m. Two main towers rest on 19.8 m. high concrete piers which are placed on concrete caissons. Dimensions of caissons are: 40.8 m. long, 18 m. wide and 31.2 m. high. Difficulties were encountered in placing one caisson. Upper part leaned over during construction under angle of 43 degrees. Erection of caisson which weighs 11,000 tons is described.—A. E. BEITLICH

Thin bridge floors concreted in Vermont winter. H. L. TILTON AND F. B. SAUNDERS. *Eng. News-Record*, June 19, 1930, V. 104, No. 25, p. 1002-1005.—In winter of 1928 Vermont department of highways was confronted with task of completing large number of 1200 bridges which were destroyed by great flood of 1927. Completion of these bridges was necessary to relieve temporary structures which would be swept away with breaking up of ice. Concrete work consisted mainly of piers, abutments and floor slabs and was made difficult by temperatures as low as —20° F. In placing concrete in piers and abutments a 2 per cent solution of calcium chloride was incorporated in 1:2½:5 mix. Materials were heated by steam, furnished in one case by steam shovel previously used for excavation. Steam jet was used in water tank and steam pipe grid under sand and stone piles. Kerosene flame heater was used in mixer. Heating operations were started 24 hours before concreting. By these methods concrete was discharged from the mixer at temperature of 75° or higher. Freshly placed concrete was protected by canvas placed over top and down sides with outlets for live steam between canvas and forms. A

temperature of 50° was maintained even in severe weather. Heat was removed after 48 hours and as late as ten days after placing, the surface of concrete was still warm when forms were removed. Floor slabs of 1:2:4 concrete 5 in. to 9 in. thick were required by specifications to be inclosed and heated for 14 days, but to expedite opening of bridges and to decrease cost of heating, high-early-strength cement was used. Materials were heated as described above. Floor slabs were protected by canvas inclosure below. Heat was supplied by coke-burning salamanders and was confined entirely to canvas inclosure. About 125 sq. ft. of floor area was allowed per salamander with extra salamanders near the walls on windy days. Use of live steam instead of salamanders was soon abandoned. As soon as the concrete was screeded and broomed, building paper was laid on it. Then a covering of hay was spread on the paper and battened down with boards. By applying the paper directly to the concrete surface heat was retained uniformly in concrete. During first 24 hours temperature beneath paper on top of slab was from 2° to 3° higher than that in heated inclosure underneath slab. Test beams 6 in. x 6 in. x 36 in. were made from concrete in slab. These were laid on the slab and cured under identical conditions. Heating was stopped 24 hours after test beams developed a compressive strength of 2000 lb. per sq. in. This strength developed in 48 to 72 hours. Due to variable moisture content of aggregate, smallest amount of water to produce workable mix was specified. The cost of winter protection varied from 10 to 15 per cent depending on the size and location of the work.—ROBERT W. ABBETT

Subsiding bridge. *Roads Rd. Constr.* (England), June 2, 1930, V. 8, No. 90, p. 198.—Part of foundations to bridge over Salwarpe, Worchestershire were found to be undermined by scour of stream. Divers discovered earth and subsoil had been removed from under one abutment to depth of six feet for length of 16 ft. and 7 ft. back from face. Concrete in bags was inserted by divers, until whole cavity was filled, and adjacent part of river bed also made good with concrete in bags, and block stone.—JOHN E. ADAMS

Welded trusses developed for bridge floor. (See ENGINEERING DESIGN —Bridges.)

BUILDINGS

Construction and shaping of skyscrapers of reinforced concrete. "Konstruktion und Gestaltung grosser Geschossbauten in Eisenbeton." STORTZ. 1930, Konrad Wittwer, Stuttgart (Germany), R. M. 6.00. Reviewed in *Zement* (Germany), May, 1930, V. 19, No. 18, p. 432.—Details of skyscraper construction are discussed and suggestions are given for architectonical effects and their construction. Book is accompanied by many valuable illustrations.—A. E. BEITLICH

Construction of reinforced concrete tower for Navy Monument in Laboe near Kiel (Germany). WILHELM HAEVERNICK. *Der Bauingenieur* (Germany), Feb., 1930, V. 11, No. 7, p. 110-2.—Tower is 68.20 m. high, 13.80 m. wide and 31.50 m. long. Under ground consists of 5 m. thick layer of marl, then loam, 3 m. thick layer of sand and marl again. Structure rests on 1 m. thick cross reinforced concrete foundation. High quality iron portland cement and high alumina cement from Hochofenwerk Luebeck were used for construction of 10-story building. Concrete pump was used for delivery of 8 to 10 cu. meters of concrete per hour.—A. E. BEITLICH

Design and construction of the main building of the German Health Museum in Dresden (Germany). CURT G. SCHINKE. *Der Bauingenieur* (Germany), March, 1930, V. 11, No. 13, p. 229-32.—Main building which is 30 m. high is reinforced skeleton structure. Covered area is 43 m. by 50 m.

Building consists of two halls, one of them being 14.8 m. high, rooms for conventions, rooms for microscopical work, library and several rooms for lectures and exhibitions. Interesting feature is ceiling construction of big hall. Detailed description is given of formwork, concrete transportation, distribution and placing.—A. E. BEITLICH

A reinforced concrete skeleton structure in Breslau (Germany). OTTO VEIT. *Zement* (Germany), May, 1930, V. 19, No. 18, p. 429-30.—Bad underground conditions made foundation on concrete piles necessary on which reinforced concrete structure of 10-story building rests. A detailed description of the construction is given.—A. E. BEITLICH

German museum in Munich. L. HOFFMANN. *Zement* (Germany), May, 1930, V. 19, No. 20, p. 470-2.—Entire building project is divided into three parts. Building which contains collections and expositions was finished several years ago; buildings for library and conventions is under construction now. Latter structure has total length of 400 m. and has several large halls; one of them, which gives room for 2000 people, is 14 m. high. Many difficulties were encountered in placing foundations. It was necessary to make 520 small excavations which were filled with concrete on which steel structures of building rest. Reinforced concrete was used for most all of the superstructure. Ceilings with great spans were placed; roofs are covered with metal.—A. E. BEITLICH

Directions for construction of reinforced rib-ceilings with hollow bricks of pumice concrete. *Zement* (Germany), May, 1930, V. 19, No. 19, p. 455-6.—Great care must be taken for concrete forms. Bricks must be thoroughly wetted before being placed. It is necessary to provide for openings in the forms for pipes in order to prevent damage by later chiseling.—A. E. BEITLICH

The new construction of the building for the newspaper "Neue Mannheimer Zeitung" in Mannheim (Germany). NORKAUER. *Zement* (Germany), May, 1930, V. 19, No. 18, p. 427-9.—Building was erected in reinforced concrete skeleton construction. High early strength cement was used. Frost periods, which exposed structure to —28° C. for a long time, did no damage to building. Details illustrate the construction of foundations for heavy machinery.—A. E. BEITLICH

Concrete bricks for building construction. *Zement* (Germany), April, 1930, V. 19, No. 16, p. 384-5.—New form of concrete brick with porous core and hard outer shell is described. Mixture of one part of cement with ten parts of aggregates (gravel, slag, volcanic ash or pumice) are used for their manufacture. Form of bricks makes construction of any kind of wall possible. An empty air space is formed in interior of wall which provides good heat and sound insulation. Costs of construction can be reduced to about 50-60 per cent of the costs of ordinary brick masonry.—A. E. BEITLICH

New Storage warehouses of the Paris-Austerlitz station. CH. DANTIN. *Genie Civil* (France), Jan. 11, 1930, V. 96, p. 29-33.—To eliminate delays on a job comprising an area of 23,000 sq. m., great care was taken to provide satisfactory forms for all parts of the structure and to insure mechanical handling of materials. Rational choice of concrete proportions and careful supervision during hardening led to successful completion ahead of date set. Proportions were: 600 liters sand, 600 liters gravel and 350 kg. cement. To obtain a check on progress of hardening, samples were taken at the time of placing each member. These specimens were tested in flexure by means of a machine of lever type and removal of forms was postponed until strength values exceeded three times theoretically allowable limit. A table was posted giving safe stress and machine reading desired for each member.—MRS. M. A. CORBIN

Control practice in reinforced concrete construction in erection of warehouse No. VII in Free Port of Stettin (Germany). HERMANN

CANTZ. *Forscherarbeiten auf dem Gebiete des Eisenbetons* (Germany), 1930, V. 34, 71 pp.—Introduction deals with general tasks of construction control of concrete and reinforced concrete jobs. Example shows control work for construction of 5-story warehouse. Preliminary tests were made in laboratory erected in neighborhood of place of construction. Properties of cement and gravel, proportioning of mix and consistency were studied, especially from economical viewpoint. Sand which was used for construction contained up to four per cent loam. In order to find out if this has any unfavorable influence on concrete, tests were carried out with sand to which 12½ per cent of loam were mixed. No decrease in strength could be observed with this admixture. All construction materials were examined, and cement was used only when its 3-day strength was satisfactory. Sand was tested for its gradation, contents of loam and organic materials. Sodium hydroxide solution of 3 per cent was used for latter purpose. Investigations concerning consistency of mortar and concrete showed certain relations between necessary amount of cement and gradation (voids and surface) of aggregates. Method was developed to determine w/c ratio for any aggregates for a given consistency when amount of cement is given. Influence of low temperatures on compressive strength of mortars was studied. Even temperatures from 0° to +8° C. showed retarding effects. Formula was derived for calculation of 28-day strength of concrete for different mixes. Strength of concrete depends on strength of cement, w/c ratio and gradation of aggregates. Special consideration was given to influence of coarse aggregates and relation between cement and concrete strength. Quality of concrete was tested during construction by means of test cubes and beams. Construction control was also applied to mixing, working and finishing of concrete. Special equipment was made for exact measuring of construction materials. Detailed description is given of concrete distribution arrangement. Special care was taken in protecting concrete over night. All parts of building were tested after construction under heavy loads and deformations measured. Entire building occupies area of 47 x 218 m. Suggestions are given for erection of testing laboratories near the job. Thirty-five illustrations and twenty-three tables are given, and several references complete the article.—A. E. BEITLICH

How to save in concrete form work. A. B. MACMILLAN. *Concrete* April, 1930, V. 36, No. 4, p. 27.—Description of forms for girders, beams and floor slabs refers to what is ordinarily termed beam-and-girder construction. In general, following lumber sizes are used: (1) For beam and girder bottoms, 2-in. plank dressed down to 1¾ in. by the width of the beam. (2) For beam and girder sides, 1⅛ in. dressed. (3) For boards of floor form panels, ⅞ in. dressed. (4) For ledgers and ribbands, 1 x 6 in. nominal size, rough or dressed (5) For cleats (or battens) on beam and girder sides, 2 x 4 in. nominal size, rough or dressed. (6) For floor form joists, 2 x 6 in. to 2 x 10 in., depending on load and span. (7) For posts and heads of jack frame, 3 x 4 in. nominal size, rough or dressed. Girder forms are first to be set up. Both girder forms and beam forms are made in three parts, namely bottom plank and two sides. Ends of girder forms are supported by blocking up from uppermost column yoke, or on special framing of 2 x 4's fitted around opening in the column form. Sides of girder are notched out for beam. Girder sides should be cut 2 in. less than length of bottom plank. Girder sides and bottom are assembled separately Boards of sides are nailed to 2 x 4 battens or cleats and are set into place, and bottom plank is likewise set into place. Beam forms are handled similarly. Beam form ends are supported on 2 x 4's nailed to sides of girder forms at level of bottom of beam sides. Sides are 2 in. less in length than the bottom plank and 1 in. shortage at each end is again filled in by beveled 2 x 4's nailed against girder sides with double-headed nails.—C. BACHMANN

How to save in concrete form work. A. B. MACMILLAN. *Concrete*, May, 1930, V. 36, No. 5, p. 35.—Layout for typical interior floor bay shows seven of floor form panels marked F-1, signifying that they are all of same size and shape

and are interchangeable. Six other panels are marked F-2, which means that they are identical in size and shape and interchangeable. A special panel only 10 in. wide, marked F-3, is placed just off center line of floor bay, and is put there as aid to shoring of slab. Typical exterior floor bay layout contains greater variety of floor form panels. With such layouts in his possession, and knowing details, form carpenter foreman will know exactly how many floor panels of each type he will need for each of bays. With posts and girts in place, joists are set in place, but are not nailed or otherwise fastened to girts. Provision is made for substantial "permanent" shores near center of floor bay, by means of special floor form strip or panel. Before any of form work of floor bay is removed these shores are set into place under panel F-3 and fastened with wedges. Rest of form work in bay may then be removed as soon as it has attained sufficient strength to be self-supporting and to support weight of form work on floor above.—C. BACHMANN

DAMS

New Pardee dam a triumph in concrete construction. L. M. JORDAN. *Concrete*, June, 1930, V. 36, No. 6, p. 27.—Beginning of work of constructing Pardee dam across the Mokelumne river near Valley Springs, Calif., consisted of construction of flume to take care of river waters, and work of excavation for foundation was successfully conducted without interruption during winters of 1927 and 1928. Dam is 358 ft. in maximum height, 241 ft. in greatest base width, and has crest length of 1,337 ft. The contract called for completion of dam within 42 months. It was actually completed 1½ years ahead of schedule time. Cement was transported to dam site over 5-mile branch line of railway that was built by the contractor. Concrete aggregate material was secured from tailings of placer mining operations 4 miles down river. After gravel had been excavated by large dragline and transferred on cars to base of washing tower, it was elevated by means of a belt conveyor, and passed down through screens in washing tower. During months of August and September, 1928, the 18,700-ft. direct aerial tramway transferred concrete to dam at rate in excess of 67,000 cu. yds. per month. It had been designed for 440,000 lbs. capacity of gravel, or 147 buckets per hour. During 79-day period it transferred some 232,800 buckets of material from washing plant to bunkers. Four electrically-driven drum mixers were used, inclined into discharge chutes that concentrated materials into control hopper positioned on the hillside below plant, which discharged into a chute terminating at the base of principal concrete tower. Daily moisture determinations of sand were made from which moisture additions were calculated. Slump tests were practiced to arrive at the total water, but judgment was based principally upon the appearance of the concrete.—C. BACHMANN

Construction of weir in Chemnitz (Germany). R. PAPP. *Der Bauingenieur* (Germany), Jan., 1930, V. 11, No. 4, p. 55-8.—River Chemnitz is damned near site of electric power station in order to furnish sufficient water for steam boilers and cooling system. Station produces 84,300 kw. with 24 steam boilers which consume 8,000 to 12,000 cu. meter of water per hour. Old weir was replaced by new modern structure, construction of which is described. —A. E. BEITLICH

Dams of Oued Fodda and Ghrib. M. TRUFFOT. *Annales des Ponts et Chaussees*, (France) Jan.-Feb., 1930, No. 1, p. 41.—Two dams, of which former was begun in April 1926, and latter during second half of 1927, constitute a vast program of irrigation of Chéliff plain in Algeria. Total capital invested is estimated at 250 million francs. The energy produced will amount to about 14 million kilowatt-hours annually. Oued Fodda dam is a gravity dam of concrete with triangular section, 5 m. wide at the crown and 72 m. wide at the toe. It is 200 m. long. The volume of concrete to be placed is approximately

270,000 cu. m. The proportion of cement varies from 150 to 300 kg. per cu. m. of concrete. Expansion joints with copper plates are spaced every 18.6 m. The rock is transported from the quarry a distance of about 400 m. It is screened and stored in silos with automatic discharge, which permit mechanical proportioning of concrete. Proportions are selected with view to avoiding segregation in chuting concrete. Density of concrete varies from 2.4 to 2.6 and 2.7. Kieselguhr in quantities equal to 3 per cent by weight of cement is mixed with latter to increase strength of cement. No consistency tests are used—the only cue is the penetration of a man's foot (shod) up to the ankle. At the time of writing 350 to 400 cu. m. were being placed per day; it was expected to raise this production to 600 to 700 cu. m. per day.—MRS. M. A. CORBIN

Construction of the dam of San Joaquin. ADOLFO ORIVE DE ALBA. *Ingenieria* (Mexico), Jan., 1930, p. 22-25.—Methods employed in construction of an earth dam with reinforced concrete core wall are described. The upstream embankment was constructed with layers 20 centimeters thick of three parts of clayey earth and one part each of sand and gravel. Layers were given slope of 2½ per cent toward center of dam for about 10 meters and then levelled with idea that any tendency toward slipping would be in direction of center rather than toward outside. Downstream embankments differ in that proportions of sand and gravel, in each layer, increase from center to facing, which contains no clay. Clayey earth was excavated by power shovels about 500 meters upstream of dam, and conveyed by dump trucks to place. Sand and gravel were excavated by hand 50 meters upstream, and conveyed by wheelbarrows and baskets to place. Mixing and compacting of materials were done by tractor plows and rollers, with the mass wet but not fluid or muddy. All of the placing of earth fill was done under the supervision of inspector responsible for obtaining proper mixture and compactness. Average cost of embankment was $1.60 per cubic meter. Stone drain at foot of downstream face of dam was constructed of tailings and heavy gravel obtained from clearing bed of river at dam site. This material was loaded into special gondola cars by hand and dumped in place. The average cost in place of such stone transported 80 meters was $0.62 per cubic meter. Careful examination was made of the clay strata in which core or cut-off wall was to start. It was discovered that strata on which dam was originally founded in 1927 was underlaid by loose layer of water-bearing sand and gravel, which might have endangered the dam. Materials for concrete were thoroughly investigated before start to determine proper proportions. Abrams' curve for water-cement strength relation was taken as guide for the following proportions adopted as standard after experiment: 26 litres of water, 50 kilograms of cement, 63 liters of sand, 114 liters of gravel, and an eight centimeter slump. Two plant set-ups were made for pouring core wall. The first set-up used two one bag mixers, to which sand and gravel were fed by gravity from overhead volume batchers which were filled by wheelbarrows. Automatic batch meter was used, and a three minute mix required. Concrete was carried to dam in special gondola cars and then dumped into inclined chute, which in turn fed vertical tube. The second set-up became necessary after about 1000 cubic meters of total 2600 cubic meters had been placed, when concrete reached height of gondola cars. New set-up used only one mixer of two-bag capacity; and concrete was transported to dam by means of cable-way above crown of dam. This cable-way, not only supported gondola car, but also, chute into which it dumped concrete. Concrete was poured continuously day and night, and amounted to approximately 30 cubic meters per eight hours. Difficulty was encountered in getting form work properly and efficiently set up, despite careful preliminary design, because of

inexperience of available carpenters. A chart of the organization, which functioned well, is given.—MILES N. CLAIR AND C. G. CLAIR

Plant producing ready mixed concrete and cement products. (See SHOP MANUFACTURE.)

Concrete molds. (See SHOP MANUFACTURE.)

MISCELLANEOUS

New method of conveying plastic concrete. GEORG GARBOTZ. *Tonind. Ztg.* (Germany), March 17, 1930, V. 54, No. 32, p. 372.—Conveying concrete from mixer to forms, by pumping through pipes, has often been unsuccessfully attempted. This "Pumpkret" process, as developed by Giese and Hell in Kiel, has been found very satisfactory on several jobs. Importance attached to this process is evidenced by formation, under leadership of Torkretgesellschaft, of an international group representing American, English and French interests, to perfect the process. Mechanical means now in use for conveying concrete, carts, cableways, chutes, and bucket belts are unsatisfactory either because of size or because of original and maintenance cost of plant. Chute method has also disadvantage of lowering quality of concrete due to extra water required. The Ransome Company with its "Concrete-Placer" conveyed plastic concrete through pipes by means of compressed air. Pneumatic method of Torkretgesellschaft is based on entirely different principle. Cement and dry aggregate, instead of wet concrete, are blown through pipes to point of pouring. At this place a water chamber provides necessary water. Bongardt process is similar to this, except that cement and aggregate are slightly dampened and are forwarded under lower pressure. Torkret process still has some disadvantages: comparatively high energy consumption and tendency to produce concrete of variable quality. In Giese "Pumpkret" method concrete is mixed in usual manner and flows into feed chamber, at the bottom of which is stirring arrangement that prevents segregation and passes concrete to vertical pump cylinder. Pump delivers it to air chamber from which it is forced through pipes with regular impulses. Pipes are of 2 mm. (0.078 in.) material and have no sharp bends. Vertical portions of line are attached to wooden frame or post and horizontal portions are placed on forms. Operation of equipment is simple. Motor, pump, feed-chamber, agitator, air chamber are mounted on four-wheeled frame. Erection of piping requires only few hours. One man is needed at pump and feed-chamber and one or two men at discharge end of pipe line. Aggregate used is not larger than 20 to 30 mm. (0.79 to 1.18 in.). Consistency of poured concrete is such that it barely flows around reinforcement. Concrete is of good quality and shows no evidence of segregation. Energy consumption is low compared to other processes: 12 H. P. for a 10 cubic meter (13.1 cu. yd.) per hour production delivered vertically 15 meters (49 ft.) and horizontally 15 meters. Against advantages of easy erection, small space requirements and simple operation there exist at this time disadvantages of limited size of aggregate and limited production, difficulties that should be overcome through further study. "Pumpkret" process represents definite advance in reinforced-concrete construction since it presents a conveying method more satisfactory from both economic and scientific viewpoint than any method heretofore employed.—A. A. BRIELMAIER

Instructions for concrete construction. Belgian Association for Standardization, 2nd edition, Aug., 1929. Reviewed in *Annales des Ponts et Chaussees*, (France), Jan.-Feb., 1930, No. 1, p. 65.—Belgian Association has attempted to work out a type of specification applicable on smaller jobs. Values are given for loading, shrinkage, variations in temperature. In discussing stresses, two methods are suggested. Former, in which no tests are made, makes use of four basic concrete mixes, stipulating grading of gravel, natural sand and varying proportions of portland cement, the Abrams cone test being used as indication of consistency. The allowable stresses are given for each of the 12 mixes

thus obtained. In second method, tests are made on 20 cm. compression cubes made under job conditions. The aggregate should be hard and clean; the choice of consistency may vary within certain limits of slump test. Ratio by weight of cement to water should exceed 1.30. Concrete should contain at least 250 kg. cement per cu. m. measured in place. It should be sufficiently compact and plastic to insure proper coating of reinforcement and avoid rust. Ratio by weight of inert particles smaller than 5 mm. to those greater than that size should be within 0.30 to 0.80. Allowable stresses will be equal to one third of the compressive strength of the cubes made in field (average of three tests) and tested at ages of 28, 14 and 7 days. Maximum allowable stresses given for four different cements vary from 50 to 90 kg. per sq. cm. Three test cubes should be made each day for first 15 days; whereupon three cubes are made each week. In no case should stresses allowable in reinforced concrete exceed those of plain concrete by more than 50 per cent. Allowable shearing stress in concrete, computed disregarding stirrups and inclined bars, should not exceed one fifth of the allowable compressive stress. Allowable bond stress should be: one tenth of the allowable compressive stress, when the ends of bars are not hooked; one fifth when hooked ends are provided. In former case stress is not to exceed 6 kg. per sq. cm.—in latter 12 kg. per sq. cm. Tensile and compressive stress of reinforcement may reach 1200 kg. per sq. cm. All parts of construction exposed to repeated load should have allowable stresses reduced accordingly, this reduction not to exceed 25 per cent. Cement used is to be one of three brands of portland cement, slow-setting, or special slag cement. If latter is used, field test method must be followed. Working of concrete shall continue until further mixing produces no change in consistency. Unless otherwise specified, tests of finished structure will be made at expense of the owner.—MRS. M. A. CORBIN

The drillhammer. "Der Bohrhammer." (New journal) Flottmann, A. G., Herne i. W. (Germany). Reviewed in *Zement* (Germany), May, 1930, V. 19, No. 20, p. 480.—Journal covers field of use and application of drilling in bridge and building construction, mines and quarries. Descriptions are given of jobs, and new inventions and improvements of equipment are discussed.—A. E. BEITLICH

Concrete as building material in American foundation jobs. H. GRIESEL. *Zement* (Germany), April, 1930, V. 19, No. 17 and 19, p. 400-2 and 452-5.—Description of methods of construction, which are generally used in America, with pre-cast concrete piles and such piles which are molded-in-place. Advantages of Raymond piles are characterized. Foundations for bridges, dams and large buildings are illustrated.—A. E. BEITLICH

Reinforced concrete for construction of coke plants. *Zement* (Germany), April, 1930, V. 19, No. 17, p. 409-10.—On account of its fire resistance, durability and economy reinforced concrete was used for a great number of modern coke plants. Construction of one is described in details. Storage bins and foundations of ovens as well as all buildings were built of reinforced concrete.—A. E. BEITLICH

Protection of metallic and non-metallic structural materials against corrosion. B. SCHEIFELE. *Der Bauingenieur* (Germany), Feb., 1930, V. 11, No. 7, p. 105-8.—Author illustrates different causes of corrosion of metals, concrete, reinforced concrete, artificial stones and wood and gives directions to prevent such action by successful protective methods.—A. E. BEITLICH

Applications of concrete construction with sliding forms. KNEES. *Zement* (Germany), June, 1930, V. 19, No. 24, p. 561-5.—Description is given of modern methods to save time and to reduce costs of forms and formwork. Special consideration is given to construction with sliding forms, which allows continuous use of one form for construction of bins, stacks, storage houses, tanks and similar structures. Different modern American and German methods are illustrated. Concrete is poured continuously without joints. Control of

homogeneity is very easy. Forms are raised in steps of approximately ¼ in. Average rate of progress is about 7 to 8 ft. per day but can be increased when high quality portland cements are used. Concrete leaves forms after approximately ten hours; after this time it is sufficiently hardened. Weight of forms, platform and laborers rests on foundations. No finishing of concrete surface is necessary since no form marks remain. Several photographs accompany article.—A. E. BEITLICH

Precast concrete caissons for piers and docks floated into place. P. W. LEISNER. *Concrete*, May, 1930, V. 36, No. 5, p. 30.—New patented method in harbor construction, successfully used in building new completed first portion of Polish harbor at Gdynia should be of interest to American builders. About four and a half linear miles of reinforced concrete floating caissons, rectangular in plan, were used in construction. Caissons were towed to their positions in harbor, sunk to rest on prepared sand and gravel foundation and given stability by sand fill. Largest caissons were 105 ft. long, 23 ft. wide and 35 ft. deep, divided into nine cells by vertical cross walls. Width of bottom, or base, was 30 ft. Weight was about 1200 long tons. Most caissons were made standard length of 60 ft., divided into five cells by vertical cross walls. Instead of following the usual practice of building these caissons in dry dock or on launching ways, contractors built them upon surface of land which was to be dredged for harbor basins. Caissons were cast in lying postion on ground, in long rows. As dredging proceeded, finished caissons gradually righted themselves on advancing slope until they floated. Dredging was done with suction dredges.—C. BACHMANN

Selling ready-mixed concrete in Erie. *Concrete*, June, 1930, V. 36, No. 6, p. 13.—Central mixing plant of the Charles H. Fry Construction Co. is well located with respect to receipt of materials and delivery of mixed concrete. A railway spur siding serves this plant exclusively. Washed sand and gravel are bought from pit about 12 miles away. Cement is received by rail, in sacks, and transported by portable conveyors to almost any point in the building. Gravel and sand are unloaded from cars to stock piles and from stock piles to bins. Plant is enclosed and roofed over, except sand and gravel bins at top. These have combined capacity of 18 cu. yd. Mixer, of 1 yd. capacity is charged by gravity from sand and gravel bins above, proportions being made by measure. Normal capacity of mixing plant may be considered 150 cu. yd. per 10 hr. day, but daily production of 175 cu. yd. has been attained. Two transit mixers of 1½ cu. yd. capacity, are supplemented by hired trucks when demand is heavy. Care is taken that water-cement ratio is held down to values consistent with various proportions. Grades of concrete supplied include 1:3:6 mix for footings and foundations in small buildings, 1:3:4 for sidewalks and floors, 1:2:4 for heavy foundation work and structural concrete work in general, and 1:1½:3 for heavily reinforced concrete work. Concrete has been delivered from plant for distances up to 16 miles, requiring about 50 minutes in time. Concrete delivered in city seldom requires haul of more than 3 miles, or 20 minutes. Base price for concrete (at plant) ranges from $7.25 per cu. yd. for the leanest mix, to $9.25 for the richest. The price for topping is from $12.00 to $14.00 per cu. yd.—C. BACHMANN

Concrete benches a necessity in greenhouses. WALTER B. BALCH. *Concrete*, May, 1930, V. 36, No. 5, p. 49.—Greenhouses use two types of soil containers. One known as a bed, is a pit in ground planked up to prevent caving of sides and to hold prepared soil in which plants are grown. Other is known as raised bench, or bench. Concrete beds built at the Kansas Agricultural Experiment Station were made 18 in. high above the ground, 3 in. at the base tapering to 2 in. at the top and extended 6 in. into the ground. Mix was 1:4 river run sand being used. Forms had to be built, but old bed walls and scraps served. For the raised beds, 1¼-in. pipe, set into block of concrete 8 in. square and 4 in. thick, was used for legs. Bottom of bench was made 3 in.

thick, and sides 3 in. thick at bottom, tapering at the top. To carry the load until the concrete had set, ¾-in. angle irons were placed across benches from leg to leg.—C. BACHMANN

Produces and delivers 3,700 cu. yd. of central-mixed concrete a day. *Pit and Quarry*, May 7, 1930, V. 20, No. 3, p. 51-54.—Description of two of Warner Company's three Philadelphia concrete plants—Berks St. yard and Christian St. yard. These receive aggregates by barges, the cement by rail in bulk. Plants are thoroughly up-to-date. Capacity of the Berks St. plant is 1,750 cu. yd. per day, that of Christian St. plant 1,000 cu. yd. per day. Eleven illustrations.—A. J. HOSKIN

West coast firm produces large volume of transit-mixed concrete. R. E. TREMOUREUX. *Pit and Quarry*, May 21, 1930, V. 20, No. 4, p. 57-58.—Describes practices of Golden Gate-Atlas Materials Co., San Francisco, Cal. Aggregates, cement, and water are measured and weighed at central plant, in batches of 4-cu. yd. each. Each batch is discharged into truck mixer which is air-tight when its doors are closed and which revolves enroute to its destination. Average mixing time is 15 min. Each of four cement tanks in plant holds 325 bbl. of cement which is handled from bulk-cement cars by pneumatic pumping. Three illustrations.—A. J. HOSKIN

ROADS AND PAVEMENTS

Concrete streets in Sicily. A. C. *L'Industria Italiana Del Cemento* (Italy), Dec. 1929, p. 8.—Article gives a description of a system of concrete street paving introduced by S. Ghilardi & Co., in which practice similar to that used in the United States is employed. Previously streets were poured in three layers, first of rich mix, second of lean mix of stone mixed with cement mortar, and third of average mix over which was plastered coat of special cement mortar. New procedure has been found to be decidedly better and consists of pouring total thickness as one layer and of one mix, applying surface mortar also contemporaneously or next morning using special quick hardening cement. —C. G. CLAIR AND M. N. CLAIR

Merchants of New Orleans beautify Canal Street. *Concrete*, May, 1930, V. 36, No. 5, p. 47.—In the improvement of Canal St. in New Orleans all old walks were removed, regardless of their condition and new walks 5 in. thick were laid in their place. Top portion was divided into squares, by brass strips, and red border 23 in. wide was made along curb and property line. Coarse aggregate for uncolored portion of top was one part Crown Point spar and one part white marble. For red border aggregate was pink Georgia marble. The red border was obtained by mixing red iron oxide into concrete.—C. BACHMANN

Various municipal works in Bromley. H. CLIFFE. *Contr. J.* (England), June 18, 1930, V. 102, No. 2662, p. 1975.—Concrete carriage ways were constructed on continuous system, a straight joint being left at end of each day's work; expansion joints were provided 150 ft. to 150 yd. apart. It was found difficult to provide satisfactory channel when tamping from the curb so 4 in. thickness of concrete 3 in. wide was laid alongside the curb floated into proper channel levels, a 4 in. by 3-in. timber being placed on such floating and carriageway tamped therefrom. When timbers are afterwards withdrawn, space is filled with fine tarmacadam, the result proving very satisfactory. In carriageways constructed in two widths, 3 ft. long rods were placed at 12 in. centres along joints, and allowed to project 18 in. from first half width laid. Only minimum water for hydration was permitted and concrete was cured with moist sand.—JOHN E. ADAMS

Overcoming paving difficulties in West Virginia. *Concrete*, May, 1930, V. 36, No. 5, p. 13.—District No. 5, West Virginia highway department comprises ten counties lying along the crest of the Allegheny highlands and encompassing the Potomac region. Because of mountainous country and un-

certain subgrades encountered, the district constructs its subgrades at least one year ahead of paving. Slides and movement in roadbed are every-day occurrences. Any pavement laid on new subgrade is almost sure to settle or move out of alignment. Once the subgrade is built, traffic is turned over the road and kept on the new location during the settling period. Grading usually entails moving from 15,000 to 50,000 cu. yds. of material. Much of work is in rock formation, unstable in many cases and prone to slide in others. Curves are frequent, banked as much as 36 in., and are made with as long radius as possible. Embankments are built around curves and along sides of cuts or along drop side of side-wall roads, taking form of heavy-base bank with a curve approaching a parabola. District Number 4, comprising twelve counties, lies to west of District 5, and while its eastern part is mountainous it slopes downward toward the Ohio valley in long rolling ridges. Extensive mining has undermined territory with honeycomb of galleries which cause settling and changing contours of surface land. Peculiar land slides have also occurred, resulting in an unlooked-for elasticity of concrete pavement. This elasticity has led to adoption of somewhat unusual practices in reinforcing slabs. Engineers have come to know just where probable movements will take place, and when another location is impossible extra reinforcing is incorporated. Steel is saved in stretches where it is not urgently needed and accumulated excess is put into slab where movement is likely to occur. Location has been turned to as only means of preventing great expense involved in efforts to overcome force of slides and settlement. Cutting subgrade back into rock or locating right-of-way along ridges or in valley bottoms is engineer's only assurance of permanency.—C. BACHMANN

WATER WORKS

New water pipes of public water works of city of Munich (Germany). LUTZ PISTOR. *Zement* (Germany), May, 1930, V. 19, No. 22, p. 516-7.—Drinking water supply for city of Munich is furnished by wells which produce water of high purity. Two pipes of approximately 50 km. length deliver water to water works. Construction of third pipe was necessary to cover requirements of growing population. Greatest part of this work was done under ground. Cross-section of tunnel was 5.5 m.² Conditions of ground and surface were very varying. Wall of pipe was 35 cm. thick. Total of 140,000 cu. meters of ground were removed, 60,000 cu. meters of concrete were placed and 120,000 m² inner surface were provided with very smooth finish. Aggregates, which were found near the job, were washed free from loam. Wells were drilled to obtain sufficient water for this purpose. Concrete mixer and distributing arrangements were located under ground. Conveyer belts and electric driven cars delivered material to laborers who placed concrete behind forms. Work was continued during winter. Aggregates were heated by means of steam pipes in bins.—A. E. BEITLICH

SHOP MANUFACTURE

Detroit concrete block plant on large production basis. M. B. WILLISTON. *Concrete*, May, 1930, V. 36, No. 5, p. 17.—Concrete products manufacturing plant of R. E. Hamilton's Sons, Inc., in Detroit, is arranged and equipped for manufacture of all sizes and shapes of solid and hollow concrete units on a large production basis. The company manufactures cinder concrete units in complete line of more than 50 different sizes and styles, as well as art stone, chimney blocks, pier caps, sills, coping tile and related specities. Production capacity is 18,000 units per day of gravel concrete block and 7,000 daily in cinder unit department. Block machines in main building consist of two automatic standard strippers each producing 6 units, and one master tamper producing 4 units per minute. In cinder unit plant there is one automatic super-stripper producing 8 units per minute. Two block racks are set

side by side on a small revolving platform, for removing newly made block. Man removing block from machine fills one rack, when platform is immediately revolved 180° This rotation brings the empty rack next to block-making machine and loaded rack on other side. Louden overhead monorail system is used in transporting newly manufactured units from machine to curing chamber and later from curing chamber to all parts of open-air storage yard. Each trolley has 8 small wheels which run on the lower flange of a continuous I-beam. Entire block manufacturing operations are handled by plant superintendent and 20 men.—C. BACHMANN

Twenty-five different units with one power stripper. *Concrete*, April, 1930, V. 36, No. 4, p. 19.—Two outstanding features about plant of the Crown Sidewalk and Block Co., Minneapolis, Minn., are the kitchen-clean appearance of stock yard and remarkable range of style and sizes of masonry units produced. Twenty-five standard units are made on one Anchor power stripper machine, equipped with quick-change attachments for production of all standard and special sizes, styles and faces required. There are 25 different piles of blocks in yard at all times, displaying as many different kinds or sizes of units.—C. BACHMANN

Concrete molds. *Rev. materiaux construction trav. publics* (France), Feb., 1930, No. 245; p. 69-70.—Molds made of concrete composed of fine sand and cement only are used for manufacture of objects of unusual shapes, to obtain very smooth surfaces and clear cut edges. At moment of making mold, concrete must be very liquid to penetrate into all the interstices. There are several methods of making these molds.—A. SIZE

Plant producing ready-mixed concrete and cement products. *Pit and Quarry*, June 18, 1930, V. 20, No. 6, p. 28-29, 60.W. G. Traver Supply Co. operates two adjacent plants in Decatur, Ill., one producing ready-mixed concrete, the other manufacturing concrete blocks and other cement products. All aggregates—sand, gravel and crushed stone—are received by rail. Mixing plant capacity is 150 cu. yd. per 9-hr. day. Aggregates, as received, are dumped into concrete hopper whence they are taken by a chain-bucket elevator, through divided hopper into two circular wooden tanks, each of 4-carloads capacity, one being used for sand, one for gravel or stone. Each bin has two gates. One gate discharges to trucks in concrete tunnel, the other to volume batcher where cement and Celite are added from sacks. Batcher discharges into 28-cu. ft. mixer, and charge is mixed from 3 to 5 min. Water is measured from a tank having calibrated glass gauge. Cement is bought in sacks and carried from cars to the mixing floor by a slat elevator. Concrete is delivered in trucks with dump bodies. Block plant is new, and is of concrete, concrete-block and structural steel construction. Elevator which supplies the mixing plant supplies this block plant by discharging through a separate chute to inclined belt conveyor which runs to top of building. Materials are discharged into two large wooden tanks, each of which is divided into two sections, thus providing separate storage of sand, gravel, crushed stone, and haydite. Slat elevator previously mentioned feeds a belt conveyor which carries cement and Celite to block plant. Bin compartments discharge to 14-cu. ft. batch hoppers. Hoppers discharge to 32-cu. ft. steel car which serves 21-cu. ft. mixer. Prepared mixture discharges into stripper block machine which has made more than 3,200 blocks in 9½-hr. day. Blocks are loaded onto steel racks and hauled on lift truck into curing kilns where they remain 36 hr. at temperature of 76°. Air is forced through kilns by compressor. Heated water supplies heat and humidity by discharge through valves into fog-like spray. Hydraulic jack is used for testing concrete cylinders and block. Six illustrations.—A. J. HOSKIN